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THE HISTOLOGY OF THE SKIN LESIONS IN VARICELLA.[1]

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Although varicella is generally regarded as a disease of childhood, the following report deals entirely with the skin lesions in adults. These cases were observed among adult male Filipinos, inmates of Bilibid Prison, at Manila, P. I.

Concerning the prevalence of this disease in the Islands, I could obtain but scanty information. In some localities it is recognized by the natives as a distinct disease and is called in the Tagalog "buluton tubig" or waterpox, to distinguish it from "buluton" or smallpox. In one of the provinces a native boy who showed the characteristic eruption of varicella was met, with his face pitted from a former attack of smallpox.

The occasional occurrence of varicella in adults is generally accepted, although some eminent authorities claim never to have seen a case. Thomas (15) (16) states that he never saw a case in an adult and that eruptions resembling varicella in adults indicate variola. Von Genser (6) has analyzed 29,250 cases of varicella and finds that 98.22 per cent occurred before the fifteenth year of life and 1.78 per cent between the fifteenth and sixty-first year. Race, climate and confinement in crowded prisons doubtless contribute to make adults more susceptible to this disease. In the cases dealt with in this paper the diagnosis was definitely established by inoculation experiments and by the histological study of the skin lesions as well as by the clinical features of the disease.

It was formerly a matter of controversy whether variola and varicella were etiologically identical and but different manifestations of one and the same infection. Hebra and certain others of the Vienna School have maintained that the two affections are identical, but most modern authorities are agreed that variola and varicella are two distinct diseases, produced by different infecting agents. The chief data bearing on this question, which the following cases present, are the occurrence of vaccination or smallpox previous to the varicella attack. In a study of thirty-eight cases of varicella, three had the face deeply pitted by a previous attack of smallpox, and of this trio two also bore scars from recent vaccinations. Of the remaining thirty-five cases, thirty-two bore either recent, or both old and recent vaccine scars. There is no record of vaccine scars in the other three cases, but it is not improbable that they had recently been vaccinated, for a general vaccination had been accomplished some time before these observations, on account of the occurrence of smallpox in the prison. If the two diseases are identical, as is asserted by Hebra, it is difficult to explain why the severe form as seen in *variola vera*, as well as the oft-repeated vaccinations, should not protect against so slight a form as varicella.

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[1] The work on which this paper is based was carried on in the Biological Laboratory of the Bureau of Government Laboratories at Manila. It was undertaken in connection with an investigation upon smallpox which Dr. W. R. Brinckerhoff and I were carrying on at the time. I am indebted to Dr. Brinckerhoff for many valuable suggestions and for the interest which he gave to this work. The opportunity for this study of varicella was afforded through the courtesy of Dr. Moulden, physician to Bilibid Prison. Funds were furnished by a grant of two Bullard Fellowships.

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Varicella is recognized as an easily communicable disease, yet less is known concerning the mode of infection than is the case with smallpox. While some authorities believe that the disease is communicable from a day or so previous to the eruption up to the time of complete healing of the skin lesions, the presence of the infectious agent in the skin lesions has not conclusively been proved by experimental inoculation.

Inoculation of children with the vesicle contents of varicella has been tried in many instances but there is great discrepancy in the results obtained. Heim (7), Vetter (20) (21), Thomas (15) (16), Czarkert (2), Fleischmann (3) (4), Buchmüller (1), Smith (12), and others were unable to produce the disease by inoculation. Fleischmann from his first series of inoculations concludes that it is not possible to produce either variola or varicella by the inoculation of varicella lymph. In seven inoculations done at a later date, he obtained a general eruption in one case and a local reaction in two. Buchmüller gives a series of thirty inoculations with varicella. There was some local inflammation in children so inoculated and in one case a general varicella eruption. He regarded this as being a chance infection rather than the result of the inoculation.

Opposed to these results are those of Hesse (8), Steiner (13), d'Heilly (9), and others. Hesse made inoculations with varicella in one hundred and fifteen cases, which resulted in a local reaction in seventeen, in a general eruption in nine, and was without result in eighty-seven cases. Hesse inoculated with purulent material and dried crusts as well as with clear lymph. Both Vetter and Thomas consider Hesse's results of doubtful value: (*a*) On account of the possibility that his positive results were due to the use of smallpox lymph instead of varicella lymph; (*b*) some cases may have been due to spontaneous infection. Vetter asserts that the inoculations should be done with the perfectly clear lymph of typical varicella vesicles and should not be performed during an epidemic, but from sporadic cases of varicella. Eimer, who has critically considered Hesse's work, concludes that only one of his cases can be accepted.

Steiner's results are, in the two cases which he gives in detail, beyond question. He inoculated two children one 4 years old and previously vaccinated, the other 2 years and not vaccinated. Neither had had varicella previous to this time. He inoculated the upper arm with perfectly clear lymph from the vesicles of a case he considered to be undoubted varicella. Four days after the inoculation there was elevation of temperature which increased, accompanied by some constitutional disturbance, up to the eighth day when a typical varicella eruption appeared. The development of the eruption together with the symptoms he describes in full. The parallelism of the two cases as regards time of onset and eruption relative to inoculation makes spontaneous infection seem improbable. He had previously inoculated eight children with varicella with positive results in six, making a total of eight successful inoculations. Of the eight cases five had been previously vaccinated, so that it seems improbable that he dealt with a mild form of variola.

The data furnished by d'Heilly's inoculations are meager. He claims to have produced an eruption in two of the cases inoculated, one after an incubation of three, the other after an incubation of seventeen days.

We see by this review that the attempts to produce varicella by inoculation show positive results in but few cases and some of these are not beyond question.

The only animal inoculations which I have found recorded are those of Freyer (5) and of Park (11). Freyer collected the fluid contents of twenty grayish-yellow, clouded vesicles, and ground it in a mortar after adding a small amount of glycerin. With this mixture he inoculated a calf without result. The calf was inoculated afterwards with vaccine lymph and reacted in a typical manner. Park inoculated two monkeys with varicella material with negative results. He points out the diagnostic value of this proceeding and cites a case in which it was used.

The only account of the histological changes in the skin lesions in varicella is that of Unna (18) (19). He takes up the changes occurring in the epidermis in the development of the vesicle and describes two types of cell degeneration which he designates "reticulating colliquation" and "ballooning" degeneration. His description of these may briefly be summarized as follows:

1. Reticulating colliquation affects chiefly the older cells of the epidermis; that is, the stratum spinosum and outer layers. The cells increase in size and in stained sections appear pale. This swelling may be followed either by a partial or total solution of the interior of the cell. The cell membrane, however, persists so that large cellular cavities are formed. If the softening of the interior of the cell is partial a coarse reticulum will be found, but if the softening is more complete the cell

will appear as a hollow chamber within which is usually a small amount of granular coagulum lying either against the nucleus or against the cell wall. By the liquefaction of the interiors of cells with the persistence of the cell walls, a reticular appearance is produced. Both nucleus and cell wall finally react to certain stains in a manner similar to fibrin.

2. Ballooning degeneration affects the cells at the base of the vesicle; that is, the Malpighian layer. The cells increase in size, lose their dense periphery and protoplasmic bridges. The nuclei become swollen, lose their network, the chromatin collects at the periphery, and direct nuclear division begins. He points out that in this case the stimulation to divide is from within the nucleus, and the centrosome and cytoplasm takes no part. Complete cell division is prevented by the early coagulation of the cytoplasm. Through this type of direct nuclear division, which takes place rapidly, large multinuclear cells are formed. Later in the process, material taking the diffuse stain appears within cells undergoing this form of degeneration, and finally both cytoplasm and nucleus stain diffusely. Thus cells presenting the ballooning as well as those presenting the reticulating types of degeneration finally undergo a "fibrinoid" transformation. In varicella lesions the ballooning degeneration is a more prominent feature than the reticulating colliquation. The formation of the vesicle is accounted for by the penetration of fluid exudate into the epidermis entering into or seperating degenerated cells and forming spaces in the tissue which enlarge and tend to coalesce to form a single chamber.

In this paper I report thirty-eight cases of varicella occurring in adult male Filipino prisoners. There had occurred in the prison about three hundred cases at the time the last observations were made and new cases were continuing to appear sporadically. Attention was first directed to them for the purpose of establishing a diagnosis. Several cases of smallpox had occurred in the prison previous to the appearance of this disease, so that it was at first important to determine whether a mild form of smallpox or a different disease was present. Later on a further study of the disease was made. This consisted of the inoculation of animals with the exudate from the skin lesions and of a study of the pathology of the skin lesions.

In two cases first seen, a few lesions were present, scattered over the surface of the body. These consisted of elevated, flat-topped pustules which possessed a central crust; this in some cases was slightly depressed. They contained a whitish, semi-fluid exudate, evidently pus. There was but little induration at the base of the pustule and the entire process was quite superficial. The exudate was collected from several of these lesions and used to inoculate one monkey and two rabbits. All inoculations were made immediately after the collection of the exudate.

Monkey No. 1.—The skin of the belly was shaved and several shallow scratches were made and inoculated with the exudate mentioned above. Four days after the inoculation the surface of the skin was elevated and slightly opaque at certain points along the scratches. One of these elevations was excised for histological study. Six days after inoculation there were small crusts situated upon the remaining scratches. These crusts were used to inoculate the corneas of rabbit No. 4. Nine days after inoculation, three small papules 2 mm. in diameter were present in the vicinity of the inoculation scratches. One such papule was excised for histological study.

About a week subsequent to the last observation the monkey was inoculated with lymph from a case of variola in man and typical variola lesions developed.

Stained paraffin sections of the skin excised four days after inoculation show the epidermis thickened over a small area, which is surmounted by a minute crust. There is no destructive process, only such a condition as might occur in the repair of an ordinary scratch. The papule excised nine days after inoculation shows a loss of epidermis over a minute area which is covered by a very delicate crust. (Such lesions were later found quite frequently in instances where the animal's belly was shaved and were regarded as minute abrasions from scratching.)

Rabbit No. 2.—The eyes were anæsthetized with two per cent cocaine solution and the exudate from the human skin lesions rubbed into shallow incisions made upon the cornea. The corneas appeared smooth after twenty-four hours and, as no process could be detected in the daily observations for a week following the inoculation, the animal was not killed.

Rabbit No. 3.—Both corneas were inoculated with the same exudate and in a similar manner as in rabbit No. 2. The corneas in this case healed rapidly and no process developed subsequently. Animal not killed.

Rabbit No. 4.—Both corneas were inoculated with the crusts obtained from the inoculation of Monkey No. 1. The corneas became nearly smooth in from twenty-four to forty-eight hours. The animal was killed three days after inoculation. In sections of the cornea there appeared a slight defect in the epithelium at the point inoculated, but no pathological process beyond that which might follow an ordinary injury was present.

A number of cases subsequently appearing among the prisoners were seen at what was evidently an earlier stage in the development of the eruption. These presented full hemispherical or oval vesicles which were easily ruptured and which contained clear fluid. Certain other cases seen with these presented lesions with a central crust surrounded by a vesicular zone containing either cloudy fluid, or whitish semi-fluid pus. Exudate was collected from both sorts of lesions and used to inoculate two monkeys.

Monkey No. 5.—The belly was shaved and the clear vesicle contents mentioned in the text was rubbed gently into superficial incisions made at intervals upon this area of the skin.

Another portion of the clear fluid was blown into the nostril of the monkey. This animal developed no skin lesion although under observations for several weeks.

Monkey No. 6.—The skin of the belly was inoculated in a similar manner with the semi-fluid pus from the cases above mentioned. No lesions developed from this inoculation.

The negative character of these inoculations indicates clearly that the disease is distinct from smallpox. The result was the same whether the pus or the clear fluid was used. The virus of smallpox, even when collected from the mildest cases, produces a typical process whether inoculated on the skin of the monkey or the cornea of the rabbit. Furthermore, the clinical aspect of the disease, now that new cases were appearing, made the diagnosis of varicella already indicated by the inoculation results, certain.

Before passing on to the description of the varicella lesions it may be well in this connection to give the results of some further experimental inoculations made at a later date. The fluid contents of vesicles was collected from three typical cases of varicella. In two cases the vesicles were perfectly clear, in the other one many vesicles were slightly clouded. The fluid collected was used to inoculate a series of seven rabbits. The mode of inoculation was first to anæsthetize the eye with a few drops of 2 per cent cocaine solution so that it could be pressed gently from its socket and kept immobile while inoculating. In most instances two or three shallow parallel incisions were made across each cornea just deep enough to penetrate the epithelium. The fluid to be inoculated was then placed upon the surface and rubbed gently into the incisions. The rabbits were killed at twenty-four hour intervals after from one to six days and the corneas fixed in Zenker's fluid. The seventh animal was allowed to live for an indefinite period.

Rabbit No. 37.—Both corneas were inoculated with cloudy fluid from vesicles of case No. 32. The animal was killed twenty-four hours after inoculation; the corneal surface was nearly smooth.

Rabbit No. 38.—Killed seventy-two hours after inoculation with vesicle from case No. 32. The corneal surface appeared smooth and without defect in epithelium. There was no conjunctivitis.

Rabbit No. 39.—The corneas were inoculated with clear fluid from vesicles of cases Nos. 34 and 35. Killed forty-eight hours after inoculation. The right eye showed marked conjunctivitis, and there were several minute whitish spots in the surface of the cornea.

Rabbit No. 40.—The corneas were inoculated with clear lymph from cases Nos. 34 and 35. Killed four days after inoculation. Corneal surface nearly smooth.

Rabbit No. 41.—Corneas inoculated with clear lymph from cases Nos. 34 and 35. Killed five days after inoculation. Corneas nearly smooth.

Rabbit No. 42.—Corneas inoculated with clear fluid from cases Nos. 34 and 35. Killed six days afterwards. Corneal surface smooth. No inflammation.

Rabbit No. 43.—Corneas inoculated with clear vesicle fluid from cases Nos. 34 and 35. This animal was not killed. The incisions of the corneal surface healed rapidly after the manner of aseptic wounds and no apparent process developed during the fortnight in which the animal was kept under observation.

In the histological study of the corneas of this series of rabbits nothing was revealed, with the exception of one case, beyond the usual process of repair which follows an uninfected wound. In rabbit No. 39 one cornea showed a marked inflammatory process. Microscopically there were collections of bacilli growing in the depth of the incision and below the epithelium. The epithelium was thin and many cells were degenerated. The adjacent corneal tissue was infiltrated with leucocytes.

In no case did the gross or the histological appearances of the inoculated cornea suggest a process beyond that of repair, except one case in which there was considerable inflammation. In the latter case the inflammatory changes were evidently caused by masses of bacteria growing in the tissue of the cornea.

Grouping this latter series of inoculations with those previously done, there were in all nine rabbits inoculated upon the cornea with the vesicle contents of varicella. Of these, five were inoculated with the clear, fluid exudate, two with the clouded fluid, and two with the semi-fluid pus; the latter material came from cases which, although at first considered doubtful, were unquestionably varicella as was proved by further observations. In no case was the inoculation followed by any specific process. Three monkeys were inoculated upon the skin, one with clear fluid, and two with semi-fluid pus from varicella lesions; all gave negative results. Thus, up to the present time it has not been possible to produce any form of the disease in animals by the inoculation of vesicle contents of varicella. Although the data furnished by the inoculation of three monkeys is meager, yet the results stand in marked contrast to those obtained through the inoculation of monkeys with variola virus.

Further study was directed to the pathological process concerned in the varicella eruption. As previously stated a study was made of thirty-eight cases and attention was paid to the development of the eruption and the general condition of the patient. A more critical study with daily observations was made of eleven of the more favorable cases. These were selected because they were seen soon after the first appearance of the eruption and were uncomplicated by the appearance of skin lesions other than varicella.

Concerning the clinical features of the disease there was nothing presented more than may be found in the text-book descriptions. The cases were usually discovered within twenty-four hours after the appearance of the eruption. In some of the severe cases there was considerable fever and constitutional disturbance, but in the majority there was no complaint of feeling ill. All degrees of severity were represented from mild cases in which there were not over a dozen lesions in the entire course of the disease to severe ones in which the lesions were thickly sprinkled over the entire surface of the body. Lesions were present in either the palms of the hands or the soles of the feet in twenty-seven of the thirty-eight cases. The following case is given in order to convey an idea of the character of the disease.

Case No. 8.—Adult male Filipino seen on June 2. Eruption appeared within last twenty-four hours. Feels rather ill. He presents two good scars from former vaccination. An eruption scattered over trunk, arms, and legs, with only three lesions on face, consists of vesicles and small red macules. The vesicles are oval or hemispherical, superficial, tense, contain clear fluid, and are situated upon a reddened area of skin. The larger vesicles measure about 5 mm., the smaller ones are barely discernible. They are easily ruptured. The macules consist of small, reddened areas of the skin, in some cases slightly elevated but barely palpable. In some such areas there is a minute central vesicle, in others the center is a rough, slightly granular elevation. Certain lesions were marked for future observation.

June 3.—Several of the vesicles observed yesterday are now slightly clouded. Many macules have developed vesicles and certain vesicles have increased in size. Lesions numerous on back.

June 4.—A great number of the vesicles have become clouded and are no longer tense. Few new lesions have developed except a number on the hands. Soft palate presents three grayish erosions. Several lesions on the face have been ruptured. One present in the scalp.

Beneath a small collodion dressing on the chest is a group of clear vesicles following the outline of the collodion.

June 6.—Many of the vesicles have dried up and are represented by thin crusts. Others persist as flaccid vessicles containing cloudy whitish fluid. No new lesions have appeared since June 4. One lesion on trunk presents a depressed thin central crust and an elevated pustular edge.

June 7.—Only three unruptured vesicles left on body. Many have disappeared or are represented by pale spots in the skin. In some cases where the remains of the vesicle have been removed there is a small, round, red area representing a defect in the epidermis. Around this is a pale, translucent zone, representing the new epithelium growing in to replace that destroyed in the lesion.

June 8.—Healing has proceeded still further. Many of the crusts have been removed leaving white, rounded areas.

Lesions were excised from the eleven cases at various stages from the earliest reddening of the skin through their entire development until healing was well advanced. The technique of incision is as follows: A fairly large-sized scalpel, which must necessarily be sharp, is all that is absolutely necessary, although a pair of mouse-tooth forceps can be used to advantage in certain instances. The fixing fluid should be already prepared and at hand. The skin is first washed with alcohol and sponged lightly with a piece of gauze or absorbent cotton to render it clean. The skin adjoining the lesion is pinched up between the thumb and forefinger so that the lesion is situated at the summit of the elevation. By holding the knife nearly flat with the surface of the skin, one cuts with a sawing motion beneath the lesion which, when removed, should be placed immediately in the fixing fluid. In certain cases when the skin about the lesion is not sufficiently loose to be pinched up by the fingers, elevation may be accomplished by seizing the skin near the lesion with the mouse-tooth forceps and then exicising. It is essential to work with a very sharp knife, otherwise the lesion is liable to become mutilated and the patient caused unnecessary pain. I would recommend this method for general purposes of diagnosis of superficial skin lesions, for the following reasons: It causes a very superficial injury amounting to scarcely more than a slight abrasion, which under ordinary conditions heals rapidly. By the thinness of the slice of tissue almost perfect fixation is obtained. By this method, in which the lesion itself is neither seized with forceps nor manipulated in any way, the topographical relations are undisturbed. The only objection to the method is that it can not be done without a certain degree of pain, for the injection of a solution of cocaine so distends the tissue that it may be impossible to acquire any conception of the original process which was present. The method of freezing the skin before excision, sometimes used, is very objectionable. The blood is destroyed and the tissue cells are so altered that the subsequent staining is affected.

The tissue was generally fixed in Zenker's fluid. Lesions were excised twelve hours, one, two, three, four, five, six, and seven days after the eruption was first noted by the patient. On account of the appearance of successive crops of vesicles, it was often possible to obtain early lesions late in the disease so that the time interval, dated from the first appearance of the eruption, forms no index as to the stage of the process present. In order to acquire a more accurate knowledge of the development of the lesions, certain ones were ringed with indelible ink at their first appearance and the subsequent changes noted.

The following description of the process is based on a study of a series of lesions of the type which appears most constant, beginning with the earliest recognizable stage and taking up successive stages until repair is well advanced. In such a series of lesions the process is found to consist of changes occurring simultaneously in both epidermis and corium. However, for purposes of description, first the changes affecting the epidermis and subsequently the changes affecting the corium will be discussed. The same order will be followed in the description of the later changes which result in the repair of the skin lesions. Following this the more unusual forms of the lesion will be described separately.

The earliest lesions are obtained by the excision of red spots which precede the formation of vesicles. The first change in the epithelial cells consists of a swelling both of the cytoplasm and of the nuclei so that the epidermis is considerably thickened over a small area. (Pl. I, fig. 1.) The process in the epidermis is ofeten not confined to a single center. It is common to find multiple distinct centers separated by normal epithelium, and multiple centers which merge one into another forming a conglomerate lesion. (Pl. I, fig. 2.) With the swelling of the cells the cytoplasm stains more faintly and becomes distinctly reticulated. The nucleus is also distended so that it appears large and hollow. These nuclei almost invariably contain one or several masses of eosin-staining material. The nuclear network and the chromatin masses are retracted away from this material so that it appears to occupy a clear space within the nucleus. There are constantly present in addition to the nuclear inclusions, small deeply staining, rounded masses, situated on the outer surface of the nuclear membrane, in the cytoplasm, or between the epithelial cells. A discussion of the cell-inclusions associated with this process will be taken up in a subsequent paragraph.

Foreign cells occur here and there in the affected areas of the epidermis. From the study of the changes in the underlying corium, it seems probable that these are cells of endothelial origin which have migrated into the epidermis. In many instance these extraneous cells are found in portions of the epidermis where there are but few cells deviating from the normal type. Thus very minute lesions of the epidermis are found in which no more than three or four cells show marked change. (Pl. IV, fig. 21.) Some of the cells which have wandered into the epidermis are in a state of good preservation and these often contain eosin-staining nuclear inclusions similar to those which occur in the epidermal cells. Others present various degrees of degeneration and many have become disintegrated. The small masses resulting from their disintegration may consist of either nuclear or cytoplasmic material, or both, and are readily distinguished.

The cell changes in the epidermis following the initial swelling are progressive. Two types may be distinguished. In that termed by Unna "reticulating colliquation," either the interior of the cell liquefies or a space is formed within it, while the periphery persists as a dense membrane. Within such hollow cells the nuclei are often collapsed, a condition possibly produced by changes in the surrounding cell fluid. This form of degeneration is not so prominent, in the varicella lesion, as that next to be described.

The term "ballooning degeneration" is given by Unna to certain changes resulting in the formation of large multinucleated cells with soft plastic cytoplasm. The first change is an increase in the size of the cell while the nucleus becomes large and vesicular; the nucleus then divides by direct division, and this process is rapidly repeated until a large number of nuclei are produced within the cell. The cytoplasm is basophilic, and in it a distinct reticulum appears. The limiting membrane and protoplasmic bridges of the cell become less distinct and after a time disappear. Such cells attain enormous dimensions. The nuclei are usually grouped in the centre of the cell, often so closely packed together that the opposing surfaces are flattened one against the other. These nuclei appear as hollow sacs with one or several masses of chromatin peripherally situated, and with an eosin-staining inclusion in the interior of each nucleus. There is scarcely any indication of a nuclear network. In the presence of such a degree of amitotic division, it is nevertheless difficult to find nuclei caught in the act of division. The chromatin in some instances projects as a septum nearly across the nucleus. The dividing split passes directly through this projecting chromatin so that an approximately equal portion goes to each of the resulting nuclei. Although this would seem, from the common occurrence of nuclei flattened against one another, to be the common form of direct division, yet it can not be considered to occur constantly in this process. Certain nuclei are dumb-bell shaped and the two portions are joined by a very thin filament. Some are lobulated and are apparently in the process of constricting off small portions of their substance which form accessory nuclei of varying size. This latter form of nuclear division is seen in a greater degree in the migrating cells and in the endothelium lining the lymphatics of the corium, than in the epithelium.

With the progressive cell changes in the epidermis, exudation becomes an important factor in the typical process. Fluid finds its way into the degenerated epithelium and separates the degenerating cells so as to form spaces filled with fluid. In this manner the formation of the vesicle is begun. That the exudate sometimes breaks into hollow cells is proved by the occasional presence of free nuclei in the smaller chambers. The exudate may at this early stage appear perfectly clear or it may contain a small amount of fibrin either in the form of a reticulum or of a granular precipitate.

The continuous escape of the exudate into the epidermis rapidly dilates the smaller chambers into a large vesicle. In case the lesion has developed from multiple centers, the various chambers are separated by septa and trabeculæ which are prone to rupture on account of the rapidity of exudation. The chamber begins to form in the middle layer of the epidermis so that a portion of the stratum spinosum is lifted up with the horny layer to form the roof, while the floor of the vesicle is at this stage wholly or partially covered with epithelial cells.

At the sides of the vesicle and in the trabeculæ, the cells become elongated and stretched through the pressure of the exudate. With the cells thus stretched, the epithelial fibers of Herxheimer become prominent. It seems evident that there is an actual production of fibers coincident with the swelling and stretching of the cells. They appear as straight fibers, with tapering ends, extending lengthwise over the surface of the epithelial cells. In some cases the cells become torn from their original attachment and the fibers then released take on a spiral or crinkly form. (Pl. II, fig. 10.) They vary much in thickness and where cells lie free in the vesicle contents they often extend directly into the cell and terminate against the nucleus.

Lying free in the vesicle contents or in groups over the floor of the vesicle and along the trabeculæ are epithelial cells showing various forms and stages of degeneration, prominent among which are the large multinucleated cells resulting from the so-called "ballooning degeneration." These cells now present further degenerative changes. The protoplasm is often condensed into a membrane about the nucleus or the group of nuclei. External to this membrane the cytoplasm is very soft in appearance, being composed of a delicate reticulum. In this delicate portion, deeply stained granules or masses appear. On the surface of such cells there are sometimes globular or elongated masses staining faint blue, which radiate from the cell like the petals of a flower. In many cases the uniformity of these bodies and their arrangement is suggestive of some sort of an organism. After studying a number of cells of this type, the observer is convinced that the masses are pseudopodia-like projections from the soft protoplasm or portions of it which have been constricted off. In some cells the so-called "acidophilic" or "fibrinoid" degeneration has become marked and the entire protoplasm appears hyaline and deeply stained with eosin. The hyaline transformation makes its first appearance about the nuclei either in the form of a dense membrane or as irregular masses.

The base of the vesicle in which there is an active exudation is almost invariably concave. The papillæ are either totally obliterated or distorted through lateral distension. The epithelium in many cases persists between these papillæ for some time after it has been destroyed over the more exposed portions. The vesicles are in some instances multilocular but the average one is unilocular and stands in marked contrast to the type of lesion found in smallpox. The common involvement of hair follicles and sweat ducts in the typical rounded vesicles indicates clearly that these structures acting alone do not produce umbilication.

After the vesicles have become fully formed, other changes occur. To the naked eye the vesicles are flaccid and no longer tense, and the fluid is clouded. This condition may be seen three or four days after the first appearance of the eruption or it may even be present earlier. The evaporation and absorption are now more rapid than the out-pouring of the exudate. The fluid within the vesicle contains more fibrin than in the early stages and phagocytes which are attracted by the dead epithelial cells are beginning to appear. The roof of the vesicle, the trabeculæ, and the cells of its lateral wall now take a diffuse stain and are apparently dead. The trabeculæ are ruptured in almost every instance and their remains are to be found projecting downward from the roof of the vesicle. The former pressure of exudate has in many instances broken peripherally beyond the boundary of the original lesion so that irregular spaces are found. The large, rounded epithelial cells lying loose on the floor of the vesicle show various degrees of hyaline changes. Some appear dense and hyaline, others are stained but faintly. The nucleus is either no longer apparent or is represented by irregular, deeply stained masses. Probably all the epidermis involved in the lesion is eventually destroyed.

In some instances a portion of the epithelium which shows none of the cell changes that are characteristic of the process, is invaded by numbers of phagocytic cells. It is possible that such infiltration of a small focus of the epidermis represents the site of a minute process in which the initial cells changes have been obscured in the infiltration which has followed. The phagocytic cells invade the normal epidermis and are found in varying number far from any well defined vesicle. Cause for their presence is not to be found in any injury to the epidermis.

In all the early lesions a pathological process is constantly found in the corium. The first change noted is the presence of eosin-staining inclusions situated usually in the nucleus, more rarely in the cytoplasm of cells. In what may be considered a very early stage in the process the eosin-staining inclusions are limited to the endothelial cells lining the small blood vessels. Later, when the process is well advanced, similar inclusions occur in a large proportion of the cells in the corium underlying the vesicle and in almost every type of cell here represented. These inclusions are associated with cell changes similar to those already described in the affected epidermis. The nuclei become distended and tend to divide by amitosis without subsequent division of the cytoplasm. Therefore, early changes of this type are found constantly in the corium as well as in the epidermis of the varicella lesion. It seems probable that the changes in the corium antedate those in the epidermis, for they are always present and often well marked in the earliest and most minute lesions.

Further changes occur in the corium at first appearing chiefly in and around the blood vessels. The process in more advanced in the neighborhood of the epidermal foci, but slight changes occur over much larger areas. The endothelial cells lining the small blood vessels present various degrees of proliferation as shown by the presence of numerous mitotic figures. Immediately around the vessels are collections of cells of which the most numerous have a large vesicular nucleus and more or less basophilic cytoplasm. It seems probable that these cells are of endothelial origin, arising from endothelial cells in the lymph spaces and vessels adjoining the blood vessels. In favor of this view is the fact that numerous mitotic figures occur in the cells lining these lymph vessels. Later in the process these endothelial cells become phagocytic. Mingled with these cells are a few lymphoid cells, and an occasional eosinophile, but the polymorphonuclear leucocyte is not represented.

In addition to the early cell changes already described, more advanced degeneration is found in cells in the vicinity of the affected vessels. The degeneration is not general; only scattered cells are affected. In some instances an entire cell appears hyaline and stains intensely. In other cells a form of nuclear fragmentation has taken place and the chromatin is scattered throughout the cell in the form of minute deeply stained globules. Portions of disintegrating cells are found occasionally. The destruction is often so far advanced that it is impossible to determine, in single instances, the type of cell affected, but it seems certain that the cells previously described as of probable endothelial origin are frequently destroyed. Changes in the corium like those already described are found in all early lesions.

In lesions taken at a later stage, during the formation of the vesicle in the epidermis, a more extensive process is found in the corium. The endothelial cells, although still most numerous about the blood vessels, are not confined to this locality. Large numbers are found scattered through the corium beneath the affected epidermis; however, the number of these cells migrating in the tissue varies considerably in different lesions.

It is not uncommon to find the capillaries and small vessels dilated just beneath the vesicle. The lymphatics also are dilated in some instances but, with the exception of those which occur immediately about the blood vessels of the lesion, there seems to be no noteworthy change affecting them.

In some lesions a great proportion of the cells in the corium below the vesicle present those peculiar changes characterized by the presence of eosin-staining nuclear inclusions and direct nuclear division. The cells are tranformed to such a degree that it is often impossible to decide to what type certain ones belong, but it is evident that nearly all varieties of cells are affected including endothelial cells, both *in situ* upon the vessel wall and free in the tissue, connective tissue cells, pigment cells, and eosinophiles. The nuclei become swollen, irregular, and lobulated, and segment irregularly into smaller nuclei, often of unequal size. The cytoplasm is increased to such an extent that cells of relatively enormous size are produced. When such large cells are of connective tissue origin, the cytoplasm presents irregular branching processes. Occluded blood vessels were found in several instances. The occlusion was due to the presence of large multinucleated cells within the vessel. In another instance a group of large multinucleated cells extended through sixteen sections (eighty micromillimeters) of the tissue in close relation to a blood vessel. It would seem that large multinucleated cells occasionally develop from the endothelium of the blood vessels and lymphatics involved in the lesion.

Later in the process phagocytosis becomes a prominent feature. The endothelial cells are found in varying numbers in the cavity of the vesicle where they are engaged in devouring the remains of epithelial cells. That portion of the corium which forms the floor of the vesicle is infiltrated with these phagocytic endothelial cells. Phagocytosis is found in a greater or less degree throughout the corium of the lesion. At this stage small numbers of polymorphonuclear leucocytes are present in the corium. On the other hand, if bacteria have gained entrance, polymorphonuclear leucocytes are found infiltrating the tissues in great numbers. Their appearance seems to be of the nature of a secondary phenomenon rather than an essential part of the process.

In the majority of lesions the active process ends soon after the destruction of the involved portion of the epidermis is completed. Many of the resulting necrotic epithelial cells appear either as dense hyaline or as faintly stained masses both free in the exudate and along the floor of the vesicle. Phagocytic cells are present in varying numbers but there is usually a large number present in the cavity of vesicles of four days duration. In the uncomplicated process, polynuclear leucocytes are relatively rare even in the older vesicles. When the destructive process is at an end, the demarcation between the living and the necrotic epithelium becomes distinct. The former grows inward over the floor of the vesicle, following the surface of the papillæ. This rapidly growing epidermis presents the same characteristics as that growing over any defect. The absence of pigment in the newly formed epidermis accounts for the whiteness of recently healed varicella lesions in Filipinos. The vesicle may persist as such until the surface beneath is completely healed, or it may be ruptured and form a thin crust on drying.

In the corium, the migrating cells gradually become reduced in numbers, the infiltration about the blood vessels is diminished, and with the repair of the defect in the epidermis the underlying tissue also returns to its normal state.

In addition to the typical lesions upon which the description of the process has been based, certain other atypical lesions occur.

Vesicle within vesicle.—In a certain percentage of the lesions there is a secondary extension of the lesion. After the vesicle is apparently well developed, it still remains tense and when seen on the following day, an increase in size is noted and the outline of the former vesicle is seen within the large lesion. The original vesicle is clouded and opaque, while the newly formed one is clear. This condition is brought about by the leakage of fluid from the cavity of the original vesicle, into the horny layer which it splits. (Pl. III, fig. 15.) It seems probable that the larger blebs and bullæ sometimes met with in these cases are formed in this way, as they appear to be very superficial.

Dry or abortive lesions.—In a small number of lesions there appears a marked localized degeneration of the epithelial cells unaccompanied by any appreciable exudation. These lesions appearing as reddened, slightly elevated spots in the gross show microscopically a portion of the epidermis wholly necrotic, the cells of which are disassociated, stain red, and are hyaline in appearance like those in the advance vesicle. Reticulating colliquation is not represented. Such lesions are simply lacking in fluid exudate. (Pl. III, fig. 16.) This condition is difficult to explain, especially when cases occur in which a majority of the lesions develop in this way. A case illustrating this condition is as follows:

Case No. 28, June 8, 1904.—A Filipino, young adult, having two old vaccination scars. The eruption has appeared within the last twenty-four hours, and is scanty. It is papular on the face and mixed with acne. Several clear vesicles, 5–6 millimeters in diameter in groin, few papules on legs. A vesicle 5 millimeters on anterior thorax, one 2 millimeters back of the shoulder, and a few small vesicles on arms and forearms.

June 9, 1904.—Eruption has increased and is scattered over the entire body. It consists of small reddened spots, the majority of which have a slightly elevated granular surface. None on hands or wrists. Face, rough and papular. Mouth negative.

June 10, 1904.—The eruption is now prôfuse and simulates an early smallpox eruption. It consists of small red papules two to four millimeters across, with granular tops. Some papules have at their summit a tiny vesicle in the center of a slightly roughened surface. A few clear, hemispherical vesicles have developed. Lesions are profuse on face and trunk, scattered over arms and legs, none on palms.

June 11, 1904.—Very few papules have become vesicular. Many lesions have faded out and practically disappeared. Following this date no new vesicles appeared and those present healed rapidly.

Lesions in the hair follicles.—It is common for hair follicles to be involved in the vesicle of varicella, but the process is at times so limited that it does not reach the surface of the skin. This occurred in two lesions excised. In one was an early process affecting the sebaceous gland and hair sheath. (Pl. II, fig. 8.) In this lesion were all the forms of cell degeneration already described. There was but slight infiltration with wandering endothelial cells and no vesicle formation. In another lesion similarly situated the sebaceous gland and the lower portion of the hair sheath were infiltrated with endothelial cells and there was a small chamber containing fluid. In places the cell degeneration could be made out to such an extent as to identify the process as varicella.

Lesions about the ducts of sweat glands.—These ducts are involved in a great many lesions. They may be seen at points along the base of the vesicle (Pl. III, fig. 15), or portions may persist within the chamber of the vesicle. Some of the minute foci are found about the epidermal portion of these ducts. (Pl. I, fig. 4.) In such instances the cells lining the duct are unaffected while the process is confined to the epidermis which surrounds it. In no case was the characteristic initial change of the process found in these ducts.

Vesicle infected by bacteria.—A certain number of lesions do not heal immediately after the full development of the vesicle. The contents becomes white and opaque and the vesicle is topped with a central crust. Vesicles presenting such an appearance have probably been ruptured, so that bacteria have gained access, although it is possible that bacterial infection may in some instances occur without the vesicle being ruptured. Such lesions exend slowly, the central crust becomes larger and surrounded by a pustular ring. The depression of the central crust as compared with the elevated pustular periphery furnishes a form of umbilication. It is plain that this lesion is secondary to varicella and has nothing to do with the active process. The umbilication is therefore of a false variety. On account of the inadvisability of excising such lesions, only one small lesion of this character was obtained. In this the pustule contents was composed almost wholly of polymorphonuclear leucocytes. The corium forming the base of the pustule was infiltrated throughout with these leucocytes and there was considerable destruction of tissue in the papillary layer. It seems probable that the permanent scars, which are not an uncommon sequence of varicella, result from lesions of this type. In the milder, uncomplicated lesions, in which the papillary layer is not preceptibly damaged, the regeneration of the destroyed epithelium constitutes perfect repair and no scar is produced.

The earliest changes in the varicella process are associated with cytoplasmic and nuclear inclusions which are found in epidermal cells, endothelial cells *in situ* within the blood vessels and lymphatics as well as those which are found migrating in the tissue, connective-tissue cells, pigment cells, and eosinophiles.

The nuclear inclusions appear at first as minute eosin-staining granules about 1 micromillimeter in diameter, situated in the nuclear sap. The nucleus may contain one or several. A clear space is formed about each nuclear inclusion and the nuclear network recedes from it. The inclusions rapidly increase in size and stain more intensely. They are most often rounded, but may be elongated or irregular. In some instances the nucleus is affected only about the inclusion, at which point it is greatly distended while the remainder appears normal. (Pl. III, fig. 18.) Very irregular and lobulated nuclei are thus produced in the cells of the corium. In the epithelial cells the whole nucleus becomes distended, the chromatin and nuclear network retracts to the periphery, leaving the interior about the inclusion clear. Direct nuclear division follows these changes, and each of the resulting nuclei usually contains a characteristic inclusion. These inclusions may attain a diameter of 6 microns when rounded and 9 microns when stretched out in elongated form. Some appear dense and homogeneous, while others are granular in character. Indefinite, deeply stained points are occasionally to be made out in them. In some instances minute granules of similar substance are grouped about a large inclusion. In one case in which the knife had passed through a sebaceous gland in excising the lesion, the nuclei were ruptured and the inclusions here showed characteristics not apparent elsewhere. (Pl. II, fig. 12, and Pl. IV, fig. 25.) They were evidently composed of a plastic substance as they had a sharp though irregular outline with rounded projections suggestive of a flowing motion. They consist of a sharply contoured body, delicately reticulated in structure. Certain ones showed a central, deep-staining granule. A certain number of nuclear inclusions are found which either are attached to the nuclear membrane or are protruding through it. They show a marked constriction where they pass through the membrane. A large proportion of these inclusions present the form of an irregular, reticulated mass without definite contour. Although these inclusions take the red in preference to the nuclear stain, they stain deeply by other methods so that they would not readily be distinguished from chromatin.

The cytoplasmic inclusions stain a dense purple by the eosin and methylene blue method, and measure from 1 to 4 micromillimeters in diameter. They are often found lying against the outer surface of the nuclear membrane, but may also occur between cells free in the connective tissue or in any position in the cytoplasm. They are constantly present in moderate numbers in the epidermis and in the cells of the corium of the early lesions, but are usually less numerous than the nuclear inclusions. They always possess a sharp contour, are most often rounded, but are occasionally irregular, and have usually a deeply stained central point. The occurrence of nuclear inclusions protruding through the nuclear membrane suggests a possible method of origin for the cytoplasmic bodies. They do not appear to be related to the fragments of disintegrated cells which are of common occurrence in the lesion.

It is difficult to reach a conclusion concerning the nature of these bodies. They are associated with the earliest changes and constitute one of the constant characteristics of the process. In a small portion of the inclusions there is some evidence of internal structure, but this is so indefinite that it carries but little weight as to their nature. A large proportion of the nuclear inclusions are so structureless and irregular that it is difficult to believe that they are living organisms. In spite of the great rapidity of the process it has not been found possible to demonstrate a multiplicative process in these bodies.

In the fresh preparation they appear homogeneous and a large number of inclusions were watched for several hours under the microscope during which time they did not change in outline. Furthermore, eosin-staining material is found within the nuclei in various other processes and in normal tissues. The writer is, however, familiar with no condition which presents inclusions closely simulating those found in varicella lesions.

As the earliest nuclear inclusions appear as red-staining granules in the nuclear sap, it is possible that they represent an increase of a substance, such as linin, present in normal nuclei. It seems to be certain that elements, readily overlooked in normal tissue, may become prominent in pathological conditions. Such an example is found in these same varicella lesions in which the epithelial fibers of Herxheimer, which are occasionally met with in normal epidermis, become increased to such an extent that they form one of the most striking features of the process. (Pl. II, fig. 10.) In this example, however, the elements in question can be traced in their transition from normal structures and are always confined to the epidermis. The nuclear and cytoplasmic inclusions, on the other hand, present a constant morphology without transitional stages connecting them with normal structures and are not confined to cells of any one tissue or type of tissue.

Another plausible hypothesis is that the inclusions represent the formation in a pathological condition of some substance not found in the normal nucleus. The reaction of the nucleus accompanying the presence of the inclusion is peculiar in that only that part about the inclusion is affected, while the remainder of the nuclear structure appears normal. If the inclusions are the result of a changed metabolism, one would expect to find a more general change. A fact to be emphasized concerning the nature of these inclusions is that they are confined to small foci, even to individual cells in the epidermis and corium. There is not sufficient evidence at hand to interpret either the nuclear or cytoplasmic inclusions and it seems preferable to suspend one's judgment until new facts are acquired bearing on this question. They are described because they form a constant and prominent feature in the varicella process.

The failure to demonstrate that the disease can be communicated by inoculation with the contents of the vesicles is against the idea that the infectious agent is contained in them. This evidence is not absolute and moreover a necessary corrollary of such experiments would be the excision and study of the area inoculated. It might well be that a slight but characteristic lesion may be produced which would not be apparent on macroscopic examination and which would not lead to the production of an exanthem. If we regarded the production of the entire disease as necessary to constitute infection, the infectiousness of smallpox in the inoculation of the calf or rabbit would be denied. On the other hand the lesions in the disease are so cellular in character and the cellular changes in their entirety so characteristic that it is hardly conceivable that the process can be produced by anything other than some agent which enters into and affects the single epithelial cells.

That the infectious agent is disseminated by the blood is rendered probable by the common occurrence in early lesions, of a process of wider distribution in the corium than is found in the epidermis and by the occurrence of isolated lesions of blood vessels far from any epidermal involvement. It seems reasonably certain that the process in the corium antedates that in the epidermis.

Certain facts brought out in this investigation may be given a practical application in the matter of diagnosis. During every epidemic of smallpox there occur cases in which there is great difficulty in diagnosis. One needs but to scan the literature to acquire a conception of the number of these difficult cases. Stelwagon (14) quotes an analysis of thirty-eight cases of error in diagnosis of smallpox, of which seventeen turned out to be varicella. There has been some dispute in regard to the nature of a widespread epidemic reported from Trinidad, whether the cases were all varicella or whether some were those of a mild form of smallpox. There is no doubt that many cases are passed over without their true nature being recognized. One can not depend absolutely on the gross appearances of the lesions or on the distribution.

It seems a matter of considerable importance to be able to distinguish from true varicella certain cases of smallpox resembling varicella, which, although mild, give rise to severe variola in other individuals.

Certain methods concerning the diagnosis of smallpox have already been suggested. The inoculation of monkeys as recommended by Park (11) is not always practicable in that monkeys are expensive and not always obtainable.

Howard (10) suggests in addition to animal inoculation, the study of sections of excised skin. The diagnosis is based upon the character of the process and the presence of *C. variolæ.*

Thompson (17) has applied a rapid method for embedding the excised lesions, by which he is enabled to obtain sections ready for study within three hours after excision.

The following methods are given, since they may be found of value in the diagnosis of cases in which there is a question of smallpox or varicella:

1. The contents of early, clear vesicles of such a case may be examined fresh under the microscope. The presence of large multinucleated cells is consistent with varicella and against smallpox. This test seems quite reliable and may be applied at the bedside.

2. The excision of a typical lesion for histological examination may be resorted to. In the smallpox lesion the presence of *C. variolæ* will furnish the diagnosis. In varicella the type of the vesicle, the ballooning degeneration and the constant presence of the described intranuclear and cytoplasmic inclusions will render certain the diagnosis. As will readily be inferred, the simple presence of definite cytoplasmic or nuclear inclusions within the epithelial cells is not sufficient to establish the diagnosis of smallpox, for both nuclear and cytoplasmic inclusions are also found in varicella. If the presence of these bodies is to be taken into account in the diagnosis one must possess a certain degree of familiarity with them, in one or both of the diseases in question, in order to determine their specificity.

3. A slower but very reliable means of diagnosis is the inoculation of a rabbit's cornea with fluid from the lesions. With smallpox lymph a variolous keratitis is produced which is evident in the roughening of the corneal surface in from twenty-four to forty-eight hours after inoculation. The inoculation of varicella lymph gives no process.

SUMMARY.

The study of lesions excised from eleven cases of varicella in adult Filipinos shows that the initial change consists in the appearance of peculiar eosin-staining inclusions within the nuclei and cytoplasm of epithelial and various other cells. Direct division of nuclei without subsequent division of the cytoplasm is associated with these inclusions. Cells undergoing these changes often attain relatively enormous dimensions (the ballooning degeneration of Unna). This type of degeneration is most prominent in the affected areas of the epidermis but occurs also in almost every type of cell in the corium. The epidermis presents also the reticulating type of degeneration, but only in a minor degree.

Following these cell changes the typical varicella process consists of a rapid destruction of small areas of the epidermis, associated with exudation and vesicle formation. The exudate penetrates the injured area of the epidermis, forcing the degenerating cells apart and forming spaces which tend to coalesce to form a single chambered vesicle. Exudative cells probably of endothelial origin are occasionally met with in the epidermis very early in the process. Collections of similar cells are found about the blood vessels of the underlying corium. Later in the process they are present in the corium in large numbers and exhibit amœboid activity and phagocytosis. The exudate filling the vesicle is at first clear and contains only fibrin and a few degenerating or necrotic epithelial cells, but later large numbers of phagocytic endothelial cells are found in it. The active destructive process is followed at once by repair. The epidermis grows in, closing the defect, and the corium returns to its normal conditions.

From the wider distribution of the process in the corium than in the epidermis and from the occasional occurrence of a process in a blood vessel far removed from any epithelial focus, it seems probable that the first change in the corium antedates that in the epidermis.

The development of the vesicle is attended by the formation, about the epithelial cells, of numerous fibers which agree very closely with the fibers of Herxheimer found in the normal epidermis. It is apparent, however, that there is actually an increased production of these fibers in epidermis stretched through the pressure of the exudate.

Several varieties of atypical lesions occur. The exudate may break into the wall of the vesicle and separate the horny layer so that a secondary vesicle is formed which includes the original, or lesions may occur practically without exudation. Some lesions are confined to the depths of hair follicles without the surface epithelium being affected. A certain number of lesions are infected by bacteria as the result of which they become pustular. In such lesions there is more or less destruction of the papillary layer which accounts for the scars frequently following an attack of varicella.

Specific nuclear and cytoplasmic inclusions are found in all varicella lesions and their appearance constitutes the earliest change observed in the tissues. They occur in epidermal cells and in various cells of the corium. The nuclear inclusions stain red or purplish by the eosin-methylene-blue method, and vary in size from 1 to 6 microns in diameter. The cytoplasmic inclusions stain a deep purple and a central granule is apparent in many. They are seldom found measuring over 4 microns. A conclusion has not been reached concerning the nature of these inclusions in varicella and no important evidence has been found in favor of the hypothesis that they are parasitic organisms.

Inoculations of the cornea of the rabbit and the skin of the monkey with the contents of varicella vesicles have in all cases yielded negative results.

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ILLUSTRATIONS.

PLATE I.

FIG. 1. A minute early lesion. The epidermis is thickened over a small area, the result of the swelling of cells. The nuclei are large and vesicular and several contain the characteristic inclusions.

2. An early varicella lesion showing multiple centers of degeneration in the epidermis. The ballooning type of degeneration is most prominent. Exudate has penetrated the epidermis, separating the cells and forming small chambers.

3. A minute varicella vesicle presenting a defect in the epidermis forming its floor. The exudate contains a small amount of fibrin. Considerable infiltration of the underlying corium.

4. The process affecting the epidermis about the duct of a coil gland, which, however, is not involved. Three large multinuclear cells resulting from direct nuclear division are present in the degenerated portion of the epidermis.

5. A minute lesion taken within twenty-four hours after the first appearance of the eruption. Exudate has penetrated the degenerated epidermis forming small spaces. This represents the beginning of vesicle formation.

6. A typical unilocular vesicle taken twenty-four hours after the first appearance of the eruption. The fluid filling the chamber contains a small amount of fibrin and a few epithelial cells which have became loosened in the exudation. The epithelium persisting beneath this chamber presents various degrees of ballooning degeneration.

PLATE II.

FIG. 7. Vesicle taken twenty-four hours after the first appearance of the eruption with lense shaped chamber extending, through the axis of which is a hair sheath. The fluid contents of this vesicle appeared perfectly clear macroscopically, but contains a small amount of fibrin. Slight infiltration about the vessels of the corium.

8. A lesion located in the depths of a hair follicle and presenting several large multinuclear epithelial cells. The surface epithelium is not affected.

9. Two characteristic cytoplasmic inclusions situated in the epidermis. X 1000.

10. Coarse fibers found in the epithelium forming the wall of the vesicle. X 1000. Stained with phosphotungstic acid-hematoxylin.

11. Flaccid, slightly clouded vesicle of two days' duration. Large amount of fibrin in exudate. Epidermis involved in lesions almost completely necrotic.

12. A large nuclear inclusion found in a sebaceous gland. Some indication of internal structure. X 1000.

13. Vesicle of four days' duration. Fluid contains large numbers of leucocytes and phagocytic cells. Epidermis is commencing to grow in at the sides.

14. Corium in the vicinity of a varicella vesicle. The pigment cell to the left of the capillary contains a large number of nuclei probably resulting from (a) mitotic division.

PLATE III.

FIG. 15. A vesicle of six days duration. A break has occurred in the lateral wall of the vesicle at some time during its development allowing the fluid to penetrate and separate the horny layers. A coil gland duct extends down from the floor of the vesicle. Repair is well advanced and the epithelium is growing over the defect upon which the vesicle is situated.

16. A minute "dry" lesion showing advanced degeneration of the epithelial cells without any appreciable fluid exudate.

17. Multinuclear epithelial cells shown at lower magnification in Fig. 4. Outline irregular, without definite cell membrane; cytoplasm presents a loose reticulum; nuclei hollow, with chromatin situated near nuclear membrane, and usually containing the specific inclusions.

18. Cells, probably endothelial in origin, situated in corium. They show localized swelling of the nucleus about the specific inclusions.

19. An atypical vesicle, multilocular in type and showing a central crust. The base is infiltrated with leucocytes.

PLATE IV.

[Camera lucida drawings with Zeiss compensation ocular No. 6; objective, 2 millimeters; aperture, 1.30.]

FIG. 20. Tissue about a small blood vessel of the corium just beneath an early varicella vesicle. An endothelial cell in situ upon the vessel wall contains a small inclusion within its nucleus. Other nuclei in the tissue about the vessel contain the characteristic red staining inclusion situated in clear spaces or vacuoles in the nucleus.

21. Skin excised early in the disease. The epidermis of the Filipino contains a large amount of pigment. A single endothelial cell containing a nuclear inclusion is shown. Another endothelial cell found in another optical plane and also containing a nuclear inclusion is not shown. The epithelial cell above shows a characteristic nuclear inclusion. The study of serial sections failed to show any other similarly affected cells in this portion of the epidermis so that it is to be regarded as a very minute lesion.

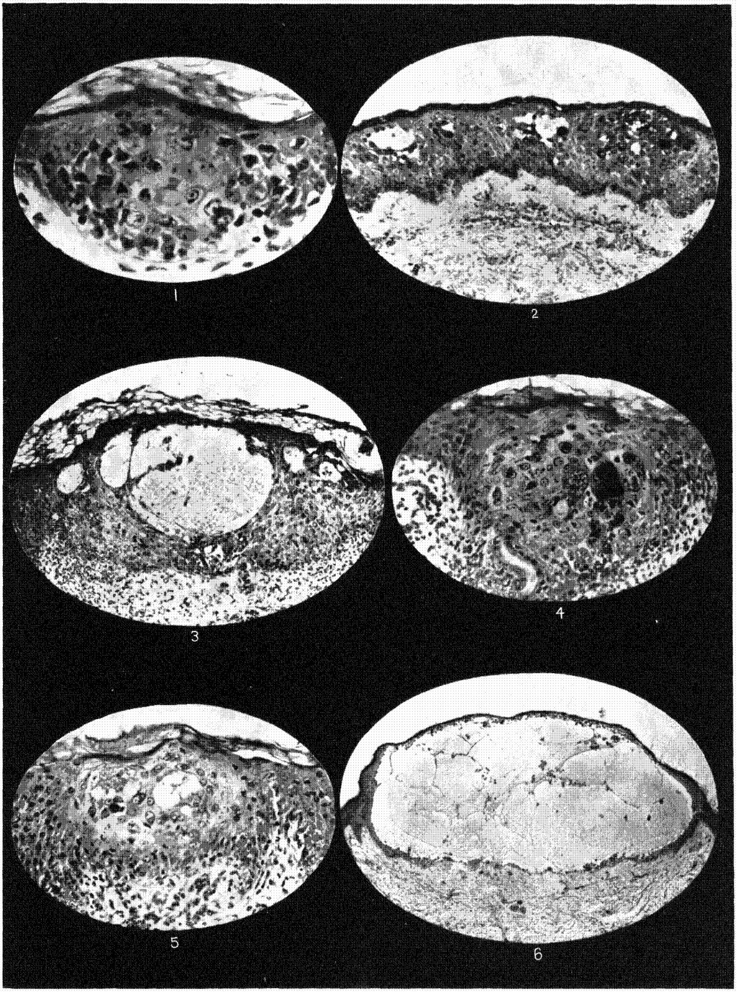
22. Nuclear and cytoplasmic inclusions in the cells of both corium and epidermis.

23. An epithelial cell possessing two nuclei, one of which appears hollow and contains a red stained body. Just outside the nuclear membrane is a more intensely stained body.

24. Epidermal cells in the floor of developing vesicle. Amitic nuclear division has here resulted in a large multinuclear cell containing inclusions in several of its nuclei, and also one extra nuclear inclusion. Other inclusions are present in adjacent cells. Some of these inclusions, especially the cytoplasmic, have deeply stained central points.

25. Cells from a sebaceous gland through which the knife passed in excision. Many of the nuclei containing inclusions have been ruptured. The inclusions are relatively large and show in certain instances a suggestion of reticular or vacuolar structure. The deeply stained granules present in two may possibly be superimposed or included chromatin from the cell nucleus.

26. An epidermal cell from a varicella vesicle showing the extension of a portion of the specific nuclear inclusion through the nuclear membrane.



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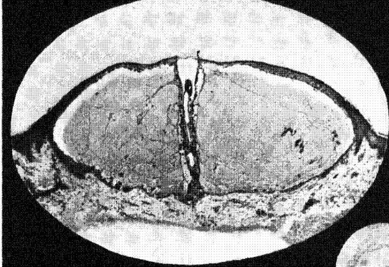

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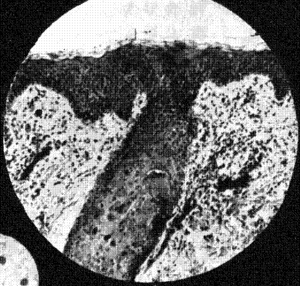

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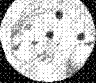

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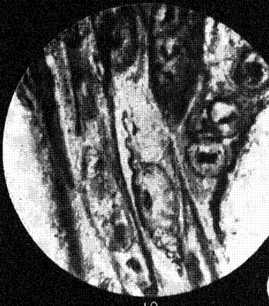

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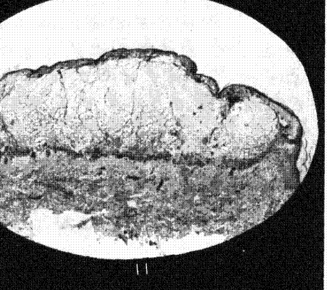

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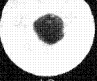

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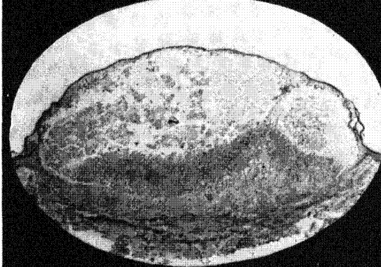

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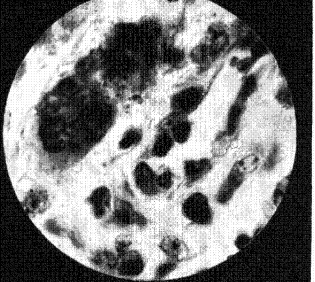

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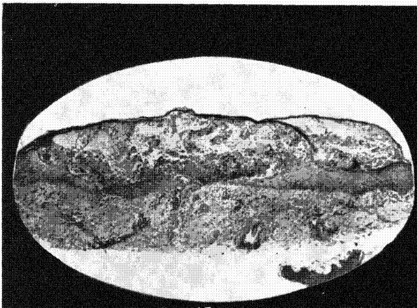
PLATE II.



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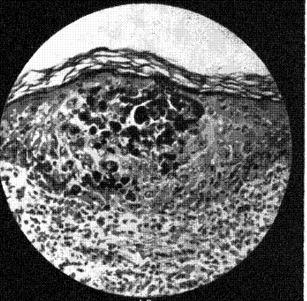

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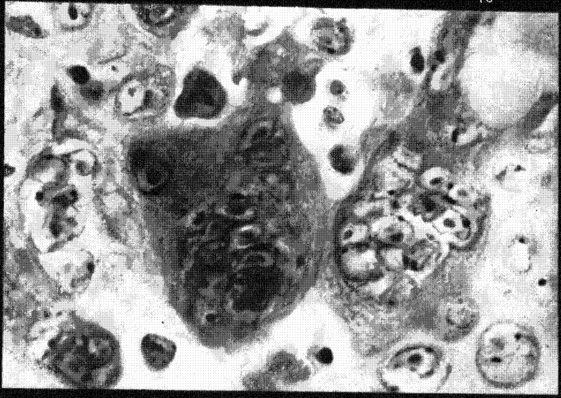

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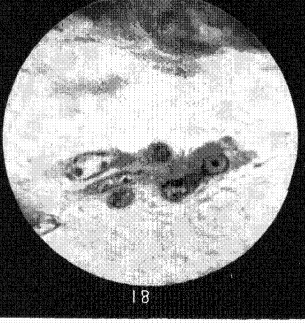

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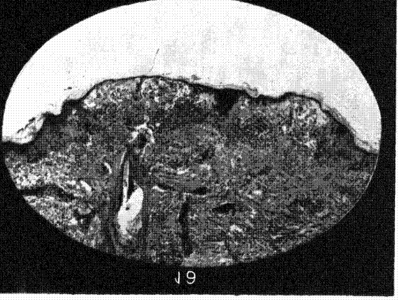

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Plate III.

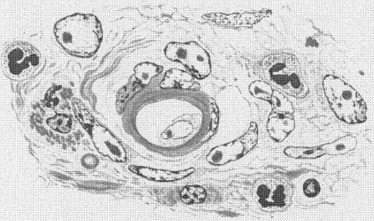

Fig. 20

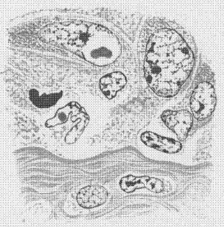

Fig. 21

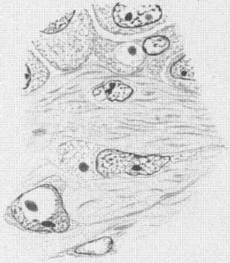

Fig. 22

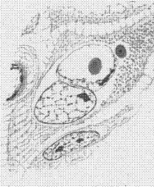

Fig. 23

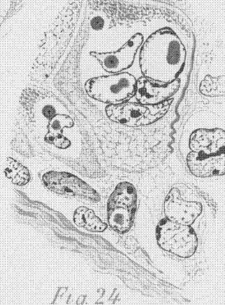

Fig. 24

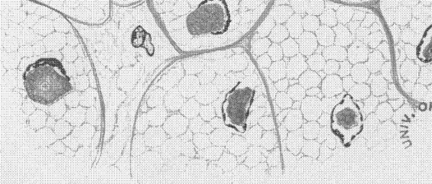

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Fig. 25

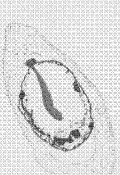

Fig. 26

E.E.Tyzzer.

THE VEGETATION OF THE LAMAO FOREST RESERVE.

By H. N. Whitford.

(*From the botanical section of the Biological Laboratory, Bureau of Science.*)

INTRODUCTION.

It is only within the last decade that the science of ecological plant geography has come to be recognized as distinct. It is therefore pertinent to review briefly the history of its development. Attention will be called only to the principal contributions.[1] Floristic plant geography will not be considered.

Grisebach[2] was the first to point out that the unit of vegetation is the *formation*. This he defines as a group of plants which bear a definite physiognomy, as a forest, a desert, or a prairie. Thurman[3] emphasized the necessity of ground water as a basis for classification and Warming[4] first clearly showed the connection between the former and formation, whereas Schimper's[5] contribution lay in a discussion of the influence of the availability of the ground water. Thus salty and cold soils were classed with dry ones because their effect upon vegetation is the same; viz, all tend to produce xerophytic structures. Up to this time the idea of *succession*, although it had been recognized as an element, had not been taken into consideration as a basis for classification. Cowles[6] was the first clearly to show that the dynamic element of vegetation brought about a succession of formations and his classification is based on the idea that habitat changes with resulting modification in the conditions for plant growth and hence an alteration in plant formations to conform with the new physical factors. Adapting to plant formations the modern idea that each topographic type has a life history, an origin, youth, middle age, and death, he first conceived of the formation as an organic whole, which is susceptible to any change modifying its environment. He laid emphasis upon the fact that the normal erosive forces change the relation of the ground-water level and so, as base level is approached, continually bring it nearer to the surface, by which means water becomes more and more available for plants. By all these workers ground water is recognized as a controlling if not the primary factor. None of the authors cited have made any serious attempt to measure the water content of the soil and the other physical factors controlling plant distribution. It remained for Clements[7] to perfect suitable instruments with which to measure the factors and, as a result of his investigations, the concept was formed "that vegetation is to be regarded as a complex organism with structures and with functions susceptible of exact methods of study." This author also developed a system of nomenclature which, with possible changes, bids fair to find acceptance by ecologists. His classification is based primarily on the physiological ground-water which he calls the *chresard,* by which form he designates the actual water in the soil which is used by the plant. This is measured in the field and because of a limit to the size of the root mass and its surrounding earth which can readily be handled, only herbaceous or small woody plants can be utilized. How the chresard of larger plants, too bulky to be handled, is to be estimated the author does not state and unless some method is provided whereby the chresard of the larger, woody plants can be measured *in situ,* or at least computed, the true chresard of forest formation can not be obtained.

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[1] For an ecological bibliography see Clements, E. C. Research Methods in Ecology. Univ. of Nebraska Pub. Co. (1905).

[2] Grisebach, A. Bericht über die Leistungen in der Pflanzengeographie (1843).

[3] Thurman, J. Essai de phytostatique appliquée à la chaine du Jura et aux contrées voicines. (1849).

[4] Warming, E. Plantesamfund (1895). German edition, translated by Knoblauch (1896).

[5] Schimper, A. F. W. Pflanzengeographie auf physiologischer Grundlage (1898). English edition, translated by Fischer (1903).

[6] Cowles, H. C. The Physiographic Ecology of Chicago and Vicinity. *Bot. Gaz.* (1901) **31**: 75.

It is obvious that the chresard varies from season to season. In temperate zones it is high during the rainy months of the growing season, lower during the dry ones, and least during those of winter. If, as Clements has done, the average of all the summer months be taken, and a classification based on this alone, then the winter condition will be left out of consideration and any classification which does not take into consideration the lowest chresard can not find a general application. There must be a recognition of the tropophytic nature of vegetation and of an unfavorable and favorable season. This is the case not only in temperate but also in tropical regions. In regions of the Tropics where the physical conditions, especially the rainfall, are more or less uniform throughout the year, the factors measured during one month will give an average for the year, but some places in the Tropics have pronounced wet and dry seasons. If the chresard measurements should be taken during the wet season only (corresponding to the summer season of temperate regions) they would be grossly misleading. It might be assumed that the winter chresard of temperate regions is nothing, but the physiological evidence is entirely against such an assumption. Coniferous trees are known to use water throughout the so-called unfavorable season and even the bare twigs of deciduous trees may give off water. In many portions of the temperate regions the conditions are such that vegetative activity is considerable during the winter and especially the very early spring months. Granted that the chresard is the controlling factor, *no general classification based upon exact methods of measurement can be made until the measurements show chresard conditions during the unfavorable as well as the favorable season.*

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[7] Clements, l c. I have not access to Clements's Development and Structure of Vegetation. *Bot. Surv. Nebr.* 7 (1904). His volume (in preparation) on the vegetation of the mountains of Colorado may throw some light on the discussion which is given below. I have obtained my information concerning his methods from the volume quoted at the beginning of this paper.

However, Clements's work marks a new epoch in ecological studies. In a word, it reduces ecology more nearly to a physiological basis and some of the mooted questions raised in this paper could have been decided had his methods been adopted. Nevertheless, it is my belief that much preliminary work can be done and indeed is necessary before careful measurements are made. Especially is this true in a region where little is known of the floristic composition of the vegetation. Attention must be focused on obtaining a knowledge of the flora, including not only an enumeration of the species but also a determination of the quantitative importance of each. Without this, no progress can be made toward an explanation of the ecological factors controlling distribution. Although the vegetation of the strand in the Tropics has been fairly well studied, but little is known of the composition of inland formations in these regions. The quantitative analysis of some forty plots, the results of which are given in this paper in such a way as to show what vegetation exists in different physiographic situations at different altitudes, is therefore a distinct contribution. During this study an effort has been made to discover what factors control distribution. How successfully this attempt has been realized will be shown by the paper which follows.

It is not too much to say that ecological botany, more than any other branch of the science, has a practical as well as a scientific value. Stripped of its business aspects, forestry is nothing more or less than forest ecology. One of the first essentials of forestry is a knowledge of the composition of the forest and the only scientific means of obtaining this knowledge is by a study of plots similar to those recorded in this paper. Indeed, with the addition of tree measurements, these plots are the "valuation surveys" of the forester. In many places in the Philippines, especially along the coasts where transportation is easily available, local forest famines already prevail. The valuable timber trees have been removed and "weed" trees have taken their place, or clearings have been made, found to be unprofitable, and have been abandoned and a knowledge of the natural succession of vegetation in these places is an absolute essential to any rational treatment which will again bring them into a good forest condition. The above discussion emphasizes only a few of the many questions which the forester must answer concerning the ecology of the forest before his calling is reduced to a scientific basis.

The foundation work of crop raising, like that of forestry, is ecology. The *habitat* of the ecologist is the *field* of the farmer. The more the farmer knows of the factors of this *habitat* the better will he be able to reduce his farming to a science, and until he makes an attempt to discover something concerning this habitat, his farming will be guess work. Unsystematized chemical and physical analyses of the soil, without any relation to the plants grown thereon, are of little or no value. The *formation* of the ecologist is the *crop* of the farmer. The factors which control the one will govern the other with this difference, that, whereas under natural conditions the waste in fallen leaves, twigs, etc., is each year returned to the soil in its entirety, in artificial vegetation the greater part is consumed, so that eventually, unless some return is made, the soil becomes depleted.

The advisability of differentiating forest from agricultural lands can not be questioned in any partially undeveloped country like the Philippines. Ecological surveys will not only do this but if they are made with due regard to the careful measurement of the physical factors, they will give a clear classification, the results of which when placed on maps will show at a glance the economic possibilities of the region investigated.

The systematic nomenclature of this paper is the one used by E. D. Merrill in his "Flora of the Lamao Forest Reserve,"[8] which is to be published simultaneously with this paper. I am indebted to Mr. Merrill for most of the identifications. Besides the various members of the Bureau of Science who have assisted me in the preparation of this paper, I am also indebted to Capt. George P. Ahern, Chief of the Bureau of Forestry, and a number of employees of his Bureau for valuable aid rendered while I was collecting the data. Where special assistance has been rendered, acknowledgment will be given in its proper place. The map accompanying this report was adapted from certain ones of the Coast and Geodetic Survey, and from a topographic map of the reserve made by the Bureau of Forestry.

GEOLOGY AND PHYSIOGRAPHY.

The group of peaks known as Mount Mariveles is on the southern end of the peninsula of land comprising the Province of Bataan, of the Island of Luzon. The meridian of 120° 30′ east of Greenwich and the parallel of 14° 30′ north latitude intersect the mountain near its summit. Rising to the height of approximately 1,400 meters, it, with the Island of Corregidor, is the most conspicuous feature of the landscape at the entrance to Manila Bay. (See map.)

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[8] *Phil. Journ. Science* (1906) **1**, Supp. 1, April 15.

The lithologic structure of Mount Mariveles shows it to be of volcanic origin. It is a mass composed largely of andesitic ejecta and of the decomposition products thereof.[9] The physiographic features which point to its being an extinct volcano are almost as striking. Rising from Manila Bay on the east, from the China Sea on the south and west, and from the lowlands near the central part of Bataan on the north, are a series of prominent ridges ending in the peaks which, with their connecting ridges form a nearly circular chain—the rim of the former crater which has an outlet to the north, by way of the Balanga River. (See map.) Between these peaks and just beneath the lowest point of the connecting ridges are the sources of the main rivers draining the mountain; the latter have cut deep cañons and have established many branches with smaller ones. With the exception of Limay Peak, which will be discussed in another connection, the mountain, with its regular cañons and ridges which begin at the base and end at the rim of the crater, suggests that in the past it was a more or less perfect cone, considerably higher than at present and similar to Mount Mayon, in the Province of Albay, Luzon. According to Becker,[10] the volcanic period which gave rise to the earlier andesitic rocks now present in the Philippines very probably occurred in the Post-Eocene upheaval. If Mount Mariveles originated at this time, then the present erosive topography of the mountain is no older than the length of the interval intervening between the Miocene and the present date; probably it is considerably younger, for the volcano must have remained in activity for some time after its origin. At present there are no signs of volcanic activity if we except some hot springs near the base of the mountain at Port Mariveles.

The condition of the mountain to-day is only one stage in the process of its destruction by the normal erosive forces. It is conceivable that its vegetative condition, because of its prominent topography of alternating ridges and cañons, is considerably different from that of some other volcanic peaks on the Islands which are in various stages of their life history. The youthful Mayon, with its cone-like, little eroded topography, or Mount Banajao, in Tayabas Province, with a physiographic condition intermediate between that of Mayon and Mariveles, will show vegetative conditions due to factors to some extent at least dependent on their respective life histories.

Lamao River Reserve.—The portion of Mount Mariveles with which this paper deals lies on its east slope and comprises an area of approximately 4,426 hectares. It is known as the Lamao River Reserve, and has a water frontage on Manila Bay of nearly 5 kilometers, extending from Cape Magarhas on the south, in a northerly direction, to Cape Quitang. These two points mark the lower ends of the main ridges which respectively are the northern and southern boundaries of the Reserve.

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[9] I am indebted to H. D. McCaskey, of this Bureau, for information concerning the lithologic structure of the mountain. See also Becker, Geo. F. Report on the Geology of the Philippine Islands. *Annual Report of the U. S. Geog. Sur.* (1901) **21**, 111, 514.

[10] *L. c.*, 567, 568.

The northern ridge extends from Cape Quiling westward on the ridge leading to Buenavista Peak (*altitude,* 1,165 meters); from thence it follows the rim of the crater to Cabcaben Peak (*altitude,* 1,406 meters). (Pl. I.) The southern boundary is the ridge which starts at Cape Margahas and runs through Limay Peak to Caybubu Peak (Pl. II) (*altitude,* 1,386 meters) and on the rim of the crater. The western and northwestern boundaries of the reserve are formed by lines which descend from Cabcaben on the south and Caybubu on the north, meeting at the bottom of the crater near the head waters of the Balanga River.

Between the north and south ridges are two main rivers—the Lamao and the Alangan. The Lamao River rises just beneath the lowest point of the rim of the crater which connects Buenavista (Pl. II) with Caybubu Peak. From its source down to within 3.5 kilometers of the shore, it lies in a cañon which varies in depth from 75 to 270 meters; below 3.5 kilometers the latter feature of the river disappears. Throughout its length it is an eroding stream, with alternating cascades and pools; near its source waterfalls of 15–20 meters and perpendicular walls 30 to 40 meters in height are prominent features; the breadth of the river at no place exceeds 12 meters. Four main branches, a number of wet-weather streams, and numerous ravines cut the slopes of the cañon of the main stream into many steep and shorter ridges and cañons; some of the details of this topography are shown by Plate II. The cañon feature of the Alangan, although not so pronounced as that of the Lamao River, is still marked. It has not been successful in working its way to the rim of the crater; indeed, the Camayuan River, a branch of the Lamao, has its head waters above that of the Alangan and collects drainage which would otherwise be diverted to it. Thus the drainage territory has been divided between two rivers and this fact has prevented either one from obtaining a sufficient supply of water so as to make cañons as deep as would one river, draining the same territory, and as a consequence the topography is not as deeply dissected as it otherwise would be. The cone-like contour of Mount Mariveles is slightly disturbed by Limay Peak, the altitude of which is 978 meters. It may either be a more resistant portion of the ridge leading from Cape Margahas to Caybubu Peak, or a portion of a rim of a smaller crater. The region to the north of it was not investigated with sufficient care to determine its true nature.

Between the Lamao and Alangan Rivers the lower third of the reserve is drained by branches of both, by the short Ayam River, and by many ravines and wet-weather streams which have their outlets in the indentations of the shore line. These dissect the gently sloping, low plateau at the base of the mountain into a number of low ridges and shallow depressions.

THE CLIMATE AND ITS INFLUENCE ON THE VEGETATION.

The classification of the vegetation used in this paper is based upon its character, and the climatic differences of the region. The climatic records for Lamao given below were gathered during a portion of my residence at that place; of themselves they are of little or no value, but comparatively, their usefulness in explaining some of the more marked characteristics of the vegetation is great.[11] They will be considered in the order of their relative importance.

Humidity.—Schimper[12] bases his climatic formations mainly on rainfall; those of the tropical lowlands fall under two heads—the tropical rainy and the tropical monsoon forests. The former are found in places where evergreen forests prevail during almost the entire year; the latter are those in which the dry districts are occupied by deciduous woodlands or savannahs. From the above it will be seen that the tropical rain forests are not necessarily those having precipitation which is uniform throughout the year; any alternation of wet and dry periods will show corresponding marked differences in the vegetation.

TABLE I.—*Average monthly rainfall, in millimeters, at Manila, 1865–1902.*

Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Total.
58	29	9.8	18.6	28.4	101.6	247.6	381	361.2	374.7	191.8	136.5	1,938.3

TABLE II.—*Rainfall, in millimeters, at three stations at Lamao compared with that for the same period at Manila for a part of the year 1905.*

	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.
Station 1	t	------	0	0.8	127	38.1	497.2	1,071.8	270.5	425.4
Station 2	------	------	t	16	139.7	40.4	------	------	------	------
Station 3	------	------	2.2	6.8	273.3	70.1	1,034.3	1,401.6	294.6	709.2
Manila	20.2	0	2.8	1.1	[13]173,8	24	346.2	594.4	212.8	239.6

In this and in the following tables station 1 is at sea level, station 2 at an elevation of 85 meters, 4 kilometers inland, and station 3 at an elevation of 640 meters, 13 kilometers inland. These two tables conclusively show well-marked wet and dry seasons both for Manila and the stations at Lamao. So slight is the rainfall during the dry season that one is surprised to find a forest in which the evergreen is as characteristic as the deciduous element and not a completely deciduous one to correspond with this climatic condition. During the season of little or no rain the surface layers of the soil are dry and the ground water level is low, yet, it is believed, a sufficiently high chresard exists to prevent the most pronounced deciduous habit from prevailing and vegetative activity from being altogether inhibited. The table shows that with an increase in altitude there is a decided increase in the rainfall. This, among other things, will account for a chresard which would be sufficiently high to assist in maintaining a nearly evergreen forest on the upper part of the mountain, although here, as well as at the base, there is a response to the xerophytic conditions of the dry season. On account of its deciduous element, the vegetation at the foot of the mountain can not be regarded as the best expression of Schimper's tropical rain forest, neither can it be classed with the monsoon forests, for the evergreen element is nearly absent in the latter.

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[11] The necessity of a base for comparative climatic data can not be too strongly emphasized. Isolated readings without such a comparison are practically worthless; on the other hand, with such data their value becomes nearly as great as would be that of continuous records. However, the readings must be made simultaneously. For the Manila records up to 1903 given here, see Algué, Rev. Jose. Climate. *Census of Philippine Islands*, 1903, 1: 87. I am indebted to R. Meyer, T. Hanley, and other employees of the Bureau of Forestry for assistance in the collection of climatic data.

[12] *L. c.*, 160, 261.

[13] The excessive rainfall for April is the highest ever recorded. It is mainly the amount which fell during the typhoon which visited the Islands on the 30th of that month.

Next to the rainfall, and especially to the precipitation as conserved in the shape of a chresard, the relative humidity (or its complement, the saturation deficit) is the most important factor in explaining ecological distribution, for just as the chresard controls the absorption, so does the saturation deficit regulate the transpiration.

TABLE III.—*Monthly and annual averages of the saturation deficit for Manila, 1883–1902.*

Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
19.3	22.4	25.8	28.2	29.3	23.3	18.6	15.2	15.2	14.5	17.3	18

As would be expected, these data show a high saturation deficit during the dry and a low one during the wet season. When compared with those for some regions in temperate zones, these figures are not exceptionally low even during the rainy season. Attempts have been made by Haberlandt,[14] Holtermann, and others to compare the transpiration in the damp Tropics with that in temperate zones. The general conclusion seems to be that in the shade the transpiration in the Tropics is much less than it is under the same condition in the temperate zone, while in open places it is greater. Holtermann draws the conclusion that for the entire twenty-four hours of an average day it is less in the Tropics than in Europe. In the region under consideration, especially during the month of July, there is almost continuous rain for two and even three weeks, yet these rains are usually accompanied by high winds and the periods between the showers show a comparatively high saturation deficit. Considering all factors, it is not believed that the lack of transpiration has any deleterious effect on the vegetation as a whole, for, up to a certain point, the more water there is retained by the plant the greater the vegetative activity.

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[14] See Burgerstein A. Die Transpiration der Pflanzen (1904) 160 to 174, for a review of the subject of the condition of transpiration in damp warm tropical regions, and for a citation of the literature.

TABLE IV.—*Average saturation deficit for Lamao and Manila at 1 p. m.*

	Feb.	Mar.	Apr.	May.
Station I	39.7	--------	--------	--------
Station II	38.1	30.8	--------	31.3
Station III	30.8	28.6	31.7	13.4
Manila	40.7	46.7	45.8	41.8

A comparison of the saturation deficit at the foot of the mountain with that of Station III shows an increase as one ascends. These data were taken at the time of the year and of the day when the transpiration is excessive. It is believed that the comparatively low saturation deficit together with the lower temperature, the effects of which will be discussed below, and the greater rainfall, help to maintain the more pronounced evergreen character of the vegetation on the slopes of the mountain in contrast with that at the base. A record of the maxima during some months of the dry season may not be out of place and it will throw some light on the differences at different altitudes. On February 26, at Station I, the saturation deficit was 53 at 2 p. m.; at the same time it was 32 at Stations II and III. The highest recorded in March was on the 1st day of that month, when it was 49 at Station II and 42 at Station III. In May on the 14th it was 42 at Station II and 16 at Station III.

Temperature.—The following tables give the comparative temperature of Manila and the various stations at Lamao (readings are in centigrade):

TABLE V.—*Mean monthly and annual temperature for Manila, 1883–1902.*

Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Average.
25	25.4	26.8	28.3	28.6	27.9	27.1	27.1	27	26.9	26.1	25.2	26.8

TABLE VI.—*Monthly and annual maxima of temperature in Manila,*[15] *1883–1902.*

Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Average.
32.1	32.9	34.3	35.5	36.1	35	33.5	33	33.3	33.3	32.2	32.1	36.3

TABLE VII.—*Monthly and annual minima of temperature in Manila,*[16] *1883–1902.*

Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Average.
17.9	18.0	18.5	20.8	22.7	22.6	22.4	22.3	22.4	21.4	20.3	18.3	17.1

[15] *The highest* recorded temperature for Manila is 37°.8.

[16] *The lowest* recorded temperature for Manila is 15°.7.

TABLE VIII.—*Average monthly temperature of three readings (7 a. m., 1 p. m., and 6 p. m.) in Manila and Lamao for a portion of 1905.*

	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.
Station I	25.7	28.5	28.5	29.7	29.6	26.6	26.5	--------
Station II	25.3	25.2	--------	28.5	--------	--------	--------	--------
Station III	21.0	22.6	24.5	23.4	22.7	21.9	23.1	22.8
Manila	25.4	28.0	29.5	29.6	28.	22.7	27.6	27.0

TABLE IX.—*Absolute monthly maxima of temperature (1 p. m.) in Manila and Lamao for a portion of 1905.*

	Feb.[17]	Mar.	Apr.	May.	June.	July.	Aug.	Sept.
Station I	32.4	35.8	36.0	36.5	34.0	34.0	32.5	--------
Station II	30.5	34.0	--------	32.6	--------	--------	--------	--------
Station III	24.6	27.0	28.6	28.0	26.0	26.2	26.2	26.0
Manila	32.5	34.9	31.7	35.5	34.4	31.9	33.0	33.9

TABLE X.—*Monthly minima of temperature (7 a. m., 6 a. m., or 6 p. m.) in Manila and Lamao for a portion of 1905.*

	Feb.[17]	Mar.	Apr.	May.	June.	July.	Aug.	Sept.
Station I	20.0	20.8	25.0	24.0	24.0	23.0	23.0	--------
Station II	18.0	19.0	22.5	23.8	--------	--------	--------	--------
Station III	17.8	18.5	20.0	22.0	20.2	20.0	21.0	20.2
Manila	18.0	20.2	23.7	24.8	24.0	22.7	23.8	24.0

These data in regard to temperature show, within each station, a rather uniform monthly average, the extremes being farther apart in the lowlands than they are on the slope of the mountain. In all cases the minima are not low, although at the higher altitude the average is much lower than near sea level. From an ecological standpoint this is important. At the same time it must be remembered that there are no physiological experiments which show that heat directly influences structure in plants; in other words, there are no ecological adaptations in them which can directly be traced to heat as their cause. Plants found in all conditions of temperature often have similar habits, all of which are due to their water and not to their heat relations.

Indirectly, temperature has a great ecological effect by influencing the condition of the atmospheric or of edaphic moisture, which control the ingress and egress of water into and from the plant. Thus, a diminution of the temperature below a certain limit lowers the chresard. However, the temperature of the region under consideration is not sufficiently low materially to influence the latter, for in the Tropics it is only in the very high mountain regions that low temperature is likely to bring the chresard below the danger point. The saturation deficit is the direct measurement of the influence of the temperature on the condition of the atmospheric moisture, so it is not necessary again to consider it in this connection.

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[17] After February 17.

However, independently of the chresard and of the atmospheric humidity, heat influences the transpiration and thus may effect ecological structure. The chresard and saturation defiicit remaining constant, a raising or lowering of the temperature respectively will increase or decrease the transpiration. A reference to the tables will show a continually lower temperature on the slopes of the mountain as compared with that at the base.[18] It is believed that this element, together with the lower saturation deficit and the greater rainfall, must be taken into consideration to explain the almost evergreen character of the forests on the mountain slopes, as compared with their decidedly deciduous aspect at the base of the mountain.

Aside from its ecological aspect, temperature has a profound influence on the floristic character of the vegetation, so that the upper regions of the mountain under consideration have floristic elements different from those of the region near the level of the sea. This contrast will clearly be shown when the plant formations are considered in detail.

Wind.—Wind is another factor affecting ecological distribution. In the absence of proper instruments no record of wind velocity was kept at Lamao. The effect of wind on vegetation, especially in exposed situations, will be discussed in another connection.

TABLE XI.—*Monthly and annual averages of the daily velocity of wind in Manila during the period 1885–1898, in kilometers.*

Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
165.9	192.8	224.8	232.7	231.4	234.5	280.0	273.8	296.0	182.3	154.5	149.3

Average, 217.8.

SOIL.

The soil of the Lamao Reserve is remarkably uniform in its physical texture and chemical composition. With the exception of that on the beach, it is all of a residual nature from the andesitic rocks which form the core of Mount Mariveles. It is usually a heavy clay, more or less impregnated with iron, which resembles laterite. However, it is not at all the laterite of Burma,[19] which is remarkable for its deficiency in certain salts, and, what is more important ecologically, its incapacity to hold water, and which supports the famous "eng" (*Dipterocarpus tuberculatus*) forests in that region. The soils of Mount Mariveles are not deficient in essential mineral salts and they show a very high capacity for retaining water. Tests made of representative specimens of the soil show that its average capacity to hold moisture is 53 per cent in weight of water, calculated on the total volume of air-dry soil. It is very probable that this power has a great deal to do with its capability of maintaining a sufficiently high chresard during the dry season, during which time the underground water level is lowered and the supply of water brought by capillarity to the surface layers is consequently less.

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[18] For literature on the effect of air temperature on transpiration see Burgerstein, l. c., 115 to 121, *especially Eberdt, O.* Die Transpiration der Pflanzen und ihre Abhängigkeit von äusseren Bedingungen (1889).

[19] Schimper, *l. c.*, 379.

There is no serious contention that the chemical constitutents of soil has any pronounced effect on ecological distribution, for the reason that nearly all soils contain the essential elements in sufficient quantities.[20] Exception must be made to the deleterious nature of strongly alkaline and salty soils, and even here the effect is physical rather than chemical. In undisturbed conditions, with the exception of the amount temporarily stored up in new growth, practically all which is taken from the soil by plants as mineral salts, is returned thereto in the shape of fallen leaves, twigs, etc.; it is only in cultivated ones where the crop is removed that they become worn out.[21] Attention will be called to peculiarities of the soil under the heading of formations.

THE PLANT FORMATIONS.

The types of vegetation on the Lamao Reserve may be divided into six formations; viz, the *Strand,* the *Bambusa-Parkia,* the *Anisoptera-Strombosia,* the *Dipterocarpus-Shorea,* the *Shorea-Plectronia,* and the *Eugenia-Vaccinium.* (See map.)

I. THE BAMBUSA-PARKIA FORMATION.

Character of the formation.—The vegetation at the base of the mountain has been given the name *Bambusa-Parkia* because it is believed that in the genera *Bambusa* and *Parkia* are exhibited forms of plants which best indicate the response in the vegetation to the ecological conditions which are obtained in the habitat in which these genera prevail. The response is such as to meet the almost xerophytic conditions present during the dry season. The genus *Bambusa,* represented by several species, has some of the ecological advantages of trees and many of those of grasses. Often reaching to a height of 15 or 20 meters, the bamboo is able successfully to compete with the dicotyledinous trees of the same height. This advantage is best utilized during the favorable season, when conditions for growth and photosynthesis are at their maximum. While none of the bamboos of the Lamao Reserve are completely deciduous during the dry season, yet the total area of the foliage is much less then than during the wet one. This is brought about in two ways. Many of the leaves of individual shoots are shed, leaving them with from one-third to one-half as many leaves as they would have during the rainy season. In this way the bamboos simulate the semi-deciduous trees with which they grow. Those which remain may reduce their transpiration surface by curling up like grass. Again, some of the *culms* die down altogether during the dry season, thus reducing the transpiration surface of the clumps from which they spring. Grasses may either form sod by sending out runners or underground shoots which radiate in all directions from a common center, or they may be cæspitose, when they are commonly known as "bunch" grass. Bamboos, like other grasses, may be represented by species of both types, although the "bunch" type is the predominant one on the Lamao Reserve. While the individual shoots are short-lived, the permanency of the "bunch" is maintained. To sum up, the half-grass and half-tree like habit of the bamboo is peculiarly fitted to a formation which is midway between the best expression of Schimper's tropical rainy and his tropical savannah forest.

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[20] For a review of the literature on this subject see Cowles, H. C. The Influence of Underlying Rocks on the Character of the Vegetation. *Bull. Am. Bureau Geography* (1901).

[21] See Livingston, B. E., Britton, J. C., and Reid, F. R. Studies on the Properties of an Unproductive Soil. *U. S. Dept. Ag., Bureau of Soils Bull.* (1905) **28.** In this paper it is maintained that "worn-out" soils may be poisoned ones.

Parkia roxburghii, the tree after which the dicotyledinous portion of the formation is named, is only one of a number which is deciduous a part of the dry season. (Pl. III.) While not so abundant as some of the other species of the same type, yet it is the largest and most conspicuous one present.

Within the *Bambusa-Parkia* formation there are many places where the bamboo element is altogether absent. This is more true of *Parkia roxburghii,* although the *Parkia* type (deciduous) is nearly always represented by some species. Careful measurements of the chresard will no doubt show constant variations in different portions of the formation although, except for a narrow margin along the banks of the rivers, these differences are not thought to be great enough to justify a subdivision of this formation into two or more coördinate ones. Rather, they are all considered to be stages, physiographic or artificial, in the life history of the vegetation which the region is able to support and which is a mixture of the bamboo and of the semi-deciduous types expressed by the names of the formation.

The map shows the general limits of the formation. Briefly, it extends from the upper limits of the littoral vegetation to a varying height on the side of the mountain. Making a liberal allowance for a tension line (ecotone) between this and the adjoining formation, it reaches an altitude of 75 meters on the south side of the reserve, while it runs up the slopes of Limay Peak as high as 175 meters. Toward its limits on the south side, tongues of it extend farther up the lower slopes of the ridges, while on the north side it seems to occupy both the tops and the slopes thereof. Here it is especially well marked on the more exposed ends of ridges having abrupt termini. The terrace of the Lamao River may or may not have isolated patches, but usually it is absent in these places. The region near the sea shows only isolated clumps of the indigenous species of bamboo, although here the dicotyledinous trees are quite as characteristic as they are farther inland.

The best expression of the *Bambusa-Parkia* formation is peculiar. The species called "boho," probably *Bambusa lumanpao*,[22] is the characteristic form. Clumps composed of fifteen or twenty culms, some dead and some alive, and 12 to 18 meters in height are on an average set at a distance of from 3 to 4 meters apart, not infrequently growing so close together that it would be found difficult to wedge one's way between the individual colonies. These make a shade so dense as practically to prevent the development of herbaceous and woody forms which are not adapted to such conditions. Among the clumps here and there are seen the trunks of isolated dicotyledinous trees. In some places there are groups of three or four individuals, usually of different species, as closely set as the bamboo colonies but more often they are 15 to 20 meters apart. Indeed, if the bamboo growth should entirely be removed and replaced by a grass such as *Saccharum spontaneum,* the aspect of the forest would very much resemble the park-like forests of the savannah or prairie regions. One has only to imagine the grass in the open spaces between the trees in these latter places to be 15 instead of 2 meters high to obtain an approximately correct idea of the aspect which the bamboo forests of the Lamao region presents. As a rule, the dicotyledinous trees overtop the bamboo growth by 6 to 10 and even by 15 meters. There are perhaps as many scattered younger trees as there are older ones which do not reach to the level of the bamboo roof. Independently of the bamboo, the canopy presented by the dicotyledinous tree element shows an extremely irregular profile. The convex portion of the latter is due to the higher semi-circular crowns of the trees overtopping the bamboo; those of the single trees form the smaller convex areas, those of the groups, the larger ones, and these may in turn form smaller irregularities which are due to the differing height of the individuals composing the groups. The bottom of the depressions between the isolated trees or groups of trees is the top of the bamboo colony. During the dry season, especially, the foliage of the bamboo growth shows a browner color than does that of the evergreen element. On the one hand, there are the usually gray tops of the deciduous and the dark green of the evergreen trees, and, on the other, the brown tone which accentuates the irregularity of the profile, and so, when it is viewed from a distance at an angle, the park-like nature of the formation is strikingly shown.

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[22] With the exception of the climbing forms, none of the bamboos have been found in flower or fruit. These identifications have been made from vegetative characters.

The floristic composition varies. Where it borders on the next one above, it partakes of the nature of the latter and imperceptibly grades into it. In a plot 2 kilometers inland, at an altitude of 30 meters, *Albizzia procera* forms a conspicuous element, but, so far as my observations go, this is the only tree which remains deciduous throughout the dry season. Besides *Parkia roxburghii,* the other trees prominent in this plot are *Oroxylum indicum, Zizyphus zonulatus, Bombax ceiba, Lagerstrœmia speciosa, Canarium villosum, Anisoptera vidaliana, Pterocymbium tinctorium, Ficus variegata, Koordersiodendron pinnatum, Wrightia laniti, Adenanthera pavonina, Albizzia saponaria, Premna cumingiana, Mangifera altissima, Aphananthe philippinensis, Artocarpus communis,* and *Buchanania florida.* Among the smaller ones are *Memecylon edule, Streblus asper, Cyclostemon bordenii, Mallotus philippinensis,* and others. Some of the ones mentioned above are deciduous during a portion of the dry season, while others are continuously green, but then they have a much lesser area of foliage than is found during the favorable time of the year. Nearer the *Anisoptera-Strombosia* formation in addition to the species just mentioned are *Shorea guiso, Dipterocarpus vernicifluus, Euphoria cinerea, Strombosia philippinensis, Aglaia harmsiana, Evodia glabra,* and *Talauma villariana.* The less frequent trees are *Endospermum peltatum, Dracontomelum cumingianum, Illipe ramiflora, Sterculia oblongata, Myristica philippensis, Gonocaryum tarlacense, Parinarium griffithianum, Palaquium tenuipetiolatum, Macaranga bicolor, M. tanarius, Carallia integerrina, Alstonia scholaris,* and others. All the species in these last two lists are evergreen throughout the dry season with this exception, that some of them may be completely deciduous for a day or two. All of them show less leaf surface during this time, and the deciduous element is nearly as striking as it is in the region nearer the shore.

The type of the *Bambusa-Parkia* formation, which has just been described probably occupies one-third of the area mapped as such. The other two-thirds come under sub-formations which are considered to be stages in development. As already indicated, isolated groups of bamboo are present throughout and these may or may not be accompanied by the dicotyledinous species named above. The *closed* bamboo forest does not approach nearer than 1½ kilometers to the shore, though "boho" and other bamboos are present near the coast line. One of these, *Bambusa blumeana,* probably an exotic form, is the species used in building operations in the Philippines. It is the tallest of the bamboos, and with its pagoda-like growth forms the most conspicuous feature overtopping the low, shrubby vegetation near the seashore. Whenever the "colonies" are closely set they form impenetrable thickets. Where *Bambusa blumeana* is planted, the colonies occur in rows along the edges of overgrown clearings.

Effect of artificial disturbances on the formation.—There is both historical and vegetational evidence that much of the area under consideration has been cultivated. Clearings called "caingins" by the natives are merely openings made in the forests by cutting and burning the vegetation. There are all degrees of this destruction, and after the existing vegetation is wholly or partially destroyed, the clearing thus made may perfunctorily be cultivated and then abandoned, or it may be more thoroughly tilled and after a number of years deserted. In any event, whatever the state of the removal of the original vegetation, the natural equilibrium has been disturbed by this means and a new but temporary habitat has been created which allows of the invasion of a type of vegetation which differs from that which has preceded it. Either these clearings may grow up to form grass lands, in which event they may become known as "cogonales," or they may be occupied by arboreal species. The nature of the vegetation which first gains an entrance depends on the extent to which the clearing is cultivated, on the nature of the surrounding vegetation, on the kind of habitat, or on disturbances after the clearing has been abandoned. It should be emphasized that the term caingin is applied to the *place* which is cleared for cultivation. It may remain this name as long as its origin is recognized, no matter what sort of vegetation may invade after it has been abandoned.

Vidal [23] first called attention to a peculiar type of tropical vegetation, prevalent near Manila, and called by the natives "parang." (Pls. III and IV.) His description of the origin of parangs is as follows:

> Abuse in the utilization, which until a very recent time was not subject to any restriction whatsoever, has reduced to shoots the masses of forest which formerly covered the lowlands, eradicating almost all good timber trees. In fact, the aspect of these tracts covered with shoots and saplings differs from the one to be observed in analogous localities of the temperate zones. Being so covered with woody vegetation and young trees, to an unpracticed observer they would appear to be regular woods. Such places are called in Tagalog "parang," a name which should find acceptance in the technical phraseology of the Philippines in the same way as has the word "jungle," which has been admitted by the foresters of British India, because new things must have new names. The "parang" might be defined as an extensive area, covered with brushwood and the trees of the invading species, which have taken the place of those existing before the cutting or burning. The study of these places has a practical importance in the great question of the throwing open of public territory for settlement, because usually they are the most salable of the unoccupied Government lands.

When one species becomes dominant in such places the term may be modified by the native name of the principal tree. Thus, on some old maps of Bataan Province one finds such combinations as "Parang de Culis" (*Memecylon edule*) or "Parang de Ligaa" (*Zizyphus*) and others. I can do no better than use this word "parang" as a general term for the types of vegetation about to be discussed, no matter what their origin, and to distinguish one type of parang from another by the generic name of the principal or characteristic species. In caingins which have been abandoned for long periods the invading vegetation often simulates that of the parang to such an extent that at times it is difficult to distinguish its origin. However, in the parang proper exotic species are rarely present, and if present, never predominate.

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[23] Vidal, D. Sebastian, *Catálogo Metódico de las Plantas Leñosas Silvestres y Cultivadas observadas en la Provincia de Manila* (1880) 9–10.

The laws controlling the invasion of plants into new habitats or into old modified ones, have long been recognized and are more or less clearly defined.[24] It must be remembered that the types of vegetation which are now to be discussed are only stages in the return to a climax formation similar to the *Bambusa-Parkia* formation, which has already been described.

Parangs.—The process of reducing the forest may be arrested at any of its stages. Usually, the original growth is not taken away at one time. If the bamboo is sought, its removal leaves large, open places between the dicotyledinous trees, but all the culms are usually not taken, and even if they are, the food supply stored in the cæspitose bases would enable the clumps to recover their normal condition so quickly that the short respite granted the undergrowth does not enable it to gain much headway. However, repeated and frequent cuttings have a tendency to thin out the bamboo growth, for with a reduction of the photosynthetic surface, less nutritive material is stored in the underground parts, and thus shoots may be removed faster than new material can be elaborated to replace the stored-up food. In this way clumps may be entirely reduced, or at least so much thinned that other vegetation will have a better opportunity to compete. The result is that many species which before were poorly developed, at once spring into prominence. Trees, shrubs, and lianas which were present in the original forest then give character to the vegetation. Of course, if any of these are removed with the bamboo, they, like the bamboo, are not *in situ* to compete with the existing vegetation. The character of the new vegetation will partake of that of the old, minus the species removed.

Dinochloa Parang.—One of the lianas found scattered in the original forest of the *Bambusa-Parkia* formation is *Dinochloa diffusa,* itself a bamboo, with a habit of growth which makes it peculiarly fitted to spread into the open places made in the forests. Where supports are present, like other lianas, it presents most of its foliage in the top of the formation. The stem may branch at long intervals. These branches may spread horizontally for some distance and then they may become upright if the necessary support is present. Many branches recline on the ground, in which case movements of soil or gathering of vegetative débris may cover these branches, which then may root at the nodes, and thus, in case older parts are destroyed, new centers originate. While *Dinochloa diffusa* was found in fruit during the two summers under observation, yet very few seedlings were noted; consequently its seedling condition remains yet to be investigated. It will be seen from the above that *Dinochloa diffusa* is well fitted to invade clearing habitats from surrounding places by means of its diffuse habit, or, if already present, it may form dense growths more rapidly in case there is any disturbance in its own habitat. If its tall support is removed, its reclining portions lie prone on the ground or near the ground, if the underbrush is able to support it. In the case where the shrubby vegetation is sufficiently strong to hold the reclining portions above ground, a roof is formed under which one may, by maneuvering, find a way through, because the shade is so dense that practically no new plants are able to gain a foothold. If the weight of the roof becomes so great that the shrubs or small trees supporting it are broken, then the *Dinochloa* roof in places rests on the ground. In this condition it is so jungle-like that it is very nearly impossible to penetrate without the use of a knife. Especially is this the case when growing with the *Dinochloa* there is a climbing palm (*Calamus*). All through the *Bambusa-Parkia* formation *Calamus mollis major*,[25] called "uay" by the natives, is found scattered. Especially when relieved of its support, portions of it lie recumbent or are intertwined among the branches of the *Dinochloa*.

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[24] See Clements, F. E., Research Methods in Ecology, 265, for a statement of the laws of invasion of plants into clearings; also Whitford, H. N., The Forests of the Flathead Valley, Montana, *Bot Gaz.* (1905) **39**: 282–283.

The north ridge of the reserve from the sea coast to a distance of 2 kilometers inland shows the best development of this climbing bamboo. Here isolated trees of the *Bambusa-Parkia* formation, especially *Parkia*, *Albizzia*, and a few clumps of *Bambusa lumanpao*, are found. Some places show the entire absence of the *Dinochloa* and simulate the more shrubby parang to be described below. The species accompanying *Dinochloa* are practically the same as those found in the other types of parang, excepting that they are more scattered where the *Dinochloa* is thickest. Indeed, no continuous stretches of the *Dinochloa* parang prevail, but, rather, patches of it are encountered alternating with areas of other types. There is no doubt that the *Dinochloa* parang is found in places where artificial conditions have not been made. In that case it is to be considered a natural and not an artificial stage in the development of the forest.

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[25] The species of the genus *Calamus* known as rattan or climbing palms go under the Spanish name "bejuco" by the natives, who have individual names for the different species. Because of their economic importance the natives are especially keen in distinguishing them. Many of the species have not been scientifically determined and such species will be designated by their common names with the understanding that these names have no general application, for they may differ in the various provinces.

Streblus-Aphananthe Parang.—In order to give an idea of the floristic composition of other types of the parang, the following three plots are tabulated. Only trees which are over 4 meters in height are enumerated. Smaller species will be mentioned in a detailed description. The area of each plot is approximately 160 square meters.

DESCRIPTION OF PLOTS.

Plot A is on an old river terrace, 3½ kilometers inland and at an altitude of 70 meters. It has a gentle slope toward the river. Plot B is in a similar situation at 2½ kilometers inland and at an altitude of 50 meters; plot C is 2 kilometers inland and at an altitude of 35 meters.

TABLE XII.

Name.	A.	B.	C.	Total.
Streblus asper	6	6	4	16
Aphananthe philippinensis	8	1	5	14
Canarium villosum	3	5	2	10
Memecylon edule	2	7	1	10
Buchanania florida	4	3		7
Anisoptera vidaliana	7			7
Linociera cumingiana	4	3		7
Oroxylum indicum	1	1	3	5
Premna nauseosa	1	4		5
Zizyphus trinervis		4	1	5
Ficus hauili	1		3	4
Harpullia arborea			4	4
Lagerstrœmia speciosa			4	4
Pittosporum pentandrum	2	2		4
Polyalthia lanceolata		4		4
Ficus sinuosa			3	3
Macaranga bicolor			3	3
Parkia roxburghii	3			3
Semecarpus perrottetii	2	1		3
Mallotus philippinensis		2		2
Guioa perrottetii	1	1		2
Breynia acuminata	1	1		2
Artocarpus communis		1		1
Evodia glabra	1			1
Litsea tersa	1			1
Polysias nodosa	1			1
Shorea guiso	1			1
Terminalia nitens			1	1
Xylopia dehiscens		1		1
Total	50	47	34	131

A mere enumeration of the species does not give an adequate idea of this parang. Its profile is exceedingly irregular (Pl. IV). Individual specimens of the taller trees, *Anisoptera vidaliana, Macaranga bicolor, Parkia roxburghii, Buchanania florida, Artocarpus communis,* and some times *Aphananthe philippinensis* overtop the others at varying heights. Disregarding the upper story, the younger trees together with mature smaller ones form a less regular profile. (See Table XII for an enumeration of the species.) Between the plots on the one hand and the "cogonales" on the other, more numerous in the tension zone or crowding in between the individuals of the lower story, are young trees or saplings of the older species and also the distinctly shrubby vegetation. *Tabernæmontana pandacaqui, Memecylon edule, Leea manillensis, Ixora cumingii, Breynia acuminata, Fluggea obovata, Micromelum pubescens, Guioa perrottetii, Streblus asper,* and *Premna nauseosa* are characteristic. By actual count, these predominate in the three plots under consideration; but the latter are varied so that the species which are found in one may or may not predominate in the others. The same may be said of the younger trees. For instance, in Plot B *Harpullia arborea* is represented by eighteen individuals, while it is not present in the other plots. In similar and even in adjoining patches of the type of parang under consideration, especially on the edges, there is found *Gmelina hystrix,* a small tree 3 to 4 meters in height, with long pendant branches, or *Mussænda grandiflora,* which accentuates its numerical importance by the large, white, bract-like calyx lobes. Among the smaller shrubs, the spiny *Plectronia peduncularis* is found throughout the different types of the parang, and *Otophora fruticosa* is but slightly less frequent. *Bridelia stipularis,* a common, subscandent shrub whose branches trail over the tops of the neighboring shrubs and small trees, has the appearance of a liana. The most common and large, woody lianas are *Uvaria rufa, Smilax bracteata, Tetracera sarmentosa, Ichnocarpus ovatifolius, Celastrus paniculatus, Cnestis ramiflora, Mucuna imbricata,* and the subscandent *Rourea multiflora,* all of which reach to the tops of the tall trees when these supports are present, or in their absence, sprawl over the tops of the lower story or even lie prostrate on the ground. Often *Dinochloa diffusa* (Pl. IV) and *Calamus mollis major* are found in this parang, which shows its close relation to the vegetation of the *Dinochloa* parang, which has already been described. Indeed, almost without exception, although their numerical importance is less, the species present in the former occur in the latter class. Another form of plant found in the parang is the smaller liana which differs from the larger one in habit as much as shrubs differ from trees. Among these the vitaceous *Cissus repens, C. japonica, C. geniculata,* and *Tetrastigma lanceolarium* are common; also there are species of other families such as *Abrus puchellus, Lygodium circinatum, Piper* sp., *Flagellaria indica,* etc. The herbaceous vegetation which appears to best advantage during the rainy season will be left to a later discussion.

Mixed parang.—In Plot A of the table given above it will be noticed that such species are present as *Anisoptera vidaliana, Shorea guiso,* and others characteristic of the *Bambusa-Parkia* formation. These trees give character to the parang. Such a type is by Vidal[25] termed a "mixed" one in contradistinction to the parang proper, where species of the *Dipterocarpaceæ* are entirely absent. In Plot B a few seedlings of *Anisoptera vidaliana* and *Shorea guiso* were noted, although there were no mature trees, and in Plot C none at all were present. It should be noted that without exception the species found in all the different types of parang are present in the original *Bambusa-Parkia* formation, and in a discussion of the floristic composition of the latter, an enumeration of other than the large tree species was omitted to save needless repetition. It may be stated, then, that the mixed parang differs from the *Bambusa-Parkia* stage not in its floristic composition but in the numerical importance of the species of which it is composed. In the parang the smaller trees and shrubs predominate over the tall bamboo and the larger dicotyledinous trees, because the shade which formerly prevented their best development, had been removed. Indeed, as in the case of the *Dinochloa* parang, isolated patches of original vegetation very much like the parang proper or the mixed one may be found in the midst of the best development of the *Bambusa-Parkia* formation, although these are only encountered in especially dry, physiographic situations. The explanation of the *Dipterocarpaceæ* in Plot A perhaps lies in the fact that the original vegetation was not destroyed as completely as that in B and C, where not only are the *Dipterocarpaceæ* absent (except seedlings) but where the total number of larger trees is less. (See Table XII.) It might be maintained that the habitats which I have designated as Plots B and C are not able to support the vegetation of A, if it were not for the fact that in closely adjoining areas, in similar habitats, the *Bambusa-Parkia* combination prevails.

Other types of a parang occur over large areas nearer the seacoast on the south side of the reserve. They extend back to a distance of 4 or 5 kilometers and in places on the north side reach an altitude of 100 meters. These show a still greater reduction of the original vegetation, before the present growth was allowed to develop. According to the nature of the reduction there are three forms of this type. They are as follows: (1) Areas which have been reduced to a greater extent than those I have discussed, so that nearly all of the original tall trees have been cut out; (2) areas in which all the trees have been cut, but not all killed; (3) areas in which all of the vegetation has been removed, the land cultivated, and then the vegetation allowed to reëstablish itself naturally. This last form, which is the "caingin," may or may not pass through the grass stage before it reaches the arboreal one.

As previously mentioned, during the inroads on the forest, the best of the bamboo and *dicotyledinous* trees are taken out first. As the cuttings cause the timber which is most desired, to retreat farther from the shore line, the difficulty of transporting the material taken out increases. After this period the less desirable timbers are removed. In this way all the taller trees may be destroyed and only those which are able to sprout from the stools will remain. In the meantime, the shrubs, vines, and worthless small trees which give character to the landscape have been given an opportunity subsequently to gain a better foothold. Even these may be removed partially for firewood, and as a result very low brush land is all which remains in the neighborhood of the towns. So various are the stages that it is difficult to classify them.

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[25] *l. c.*, 10.

Largerstroemia-Zizyphus parang.—This form of parang has been named after *Lagerstrœmia speciosa* and *Zizyphus trinervis* because these two species predominate or at least give character to the landscape. I believe that both of them owe their place in this type to their persistent habit of sprouting from the base of the trunk after the tree has been cut. In this case they form low, shrubby trees which, with the other associated species, compose the type. In addition to the two tree species mentioned, in one plot of approximately 160 square meters, the following are common: *Bridelia stipularis, Premna nauseosa, Leea manillensis, Ficus hauili, Oroxylum indicum, Albizzia procera, Cordia blancoi, Harpullia arborea, Litsea tersa, Semecarpus perrottetii, Ficus sinuosa, Streblus asper, Canarium villosum, Tabernamontana pandacaqui, Otophora fruticosa.* With the exception of *Oroxylum indicum* and *Albizzia procera,* there is a tendency for this type to form an almost level top which is about 3 meters in height and which is thickly covered with herbaceous and woody vines; thus a dense shade is formed because of which, species not already present are practically excluded. However, *Oroxylum indicum* and *Albizzia procera* stand isolated above this raised platform and during the dry season their bare limbs are in striking contrast to the evergreen vegetation below. In other places *Polysias nodosa,* with a rosette of large pinnate leaves, rises to a height which is twice or thrice that of the green lower story.

Each partial attempt to clear such vegetation, or any further inroads made upon it to secure firewood and construction timbers of the lowest grade, tends only still further to reduce the coppice vegetation, or it gives greater opportunity for the growth of species like *Bridelia stipularis* and lianas of various sorts. In this way, just as a closely cropped lawn increases in thickness, the parang gains in density and loses in height.

It will be seen from the above reduction series that all stages of the parang may be obtained from the climax formation of the *Bambusa-Parkia formation* to that of the low *Lagerstrœmia-Zizyphus.* Many intermediate conditions were studied. In some places *Premna nauseosa* or *Gmelina hystrix* give a different floristic composition to the parang; but whatever the species, the ecological type is the same, namely, the coppice form, mixed with small trees having scandent branches and many small woody vines. The species which are thus reduced invariably reach a good height if they are given an opportunity to develop and they are always found as taller trees in the bamboo forests or in more xerophytic physiographic situations within that forest.

The interpretation of the genetic degeneration of the *Bambusa-Parkia* formation given above is based almost entirely on comparative observation. Different stages from the lowest to the highest type may be seen lying adjacent to each other in a single habitat. These places usually adjoin the more reduced stages, viz, the cultivated clearings and cogonal. In two instances the progress of the vegetation on actual cuttings was observed at intervals throughout a period of fourteen months. Both, abandoned before completion, were made in the *Streblus-Aphananthe* type with the evident intention of clearing the land for cultivation. Many of the larger trees were left and in some places in the same clearing only slight inroads were made on the standing vegetation. An observation of these stages at later intervals, showed an incomplete development of all the forms of the parang just described.

It will be noted that no mention has been made of the vegetation occupying *total* clearings. It has been seen how the forest gradually has been reduced to the parang stage. It is only one step further to destroy it entirely. In the case of the parangs discussed, the forest is not cleared and prepared for cultivation; while in that of clearings the whole of the vegetation may be removed, the land tilled for a number of years and then abandoned, or what is more often the case, patches of it may be denuded, or large trees left standing. It will at once be seen that the resultant nature of the vegetation which invades these clearings when they are once more left to nature depends on their condition of reduction. Let it be assumed that the reduction is complete. Grass lands may then predominate in such clearings and a discussion of the causes of their development will first be given.

Cogonales.—Clearings in the Philippine forests or on their borders, which are covered by grasses, are known as "cogonales" (Pl. V), but there are no places on the Lamao forest reserve where the latter appear as the climax vegetation. Without exception, they are only stages in the reëstablishment of the normal vegetation removed by man. The first periods in the development of vegetation in caingins, in the best expression of the *Bambusa-Parkia* forest, have not come under my observation, but it is not thought that they differ materially from those in the parang after it has been well established or indeed in clearings made in the *Anisoptera-Strombosia* forests to be discussed below. Usually, such clearings are made on the borders of others and consequently, when abandoned, many seeds from these places find early lodgment. However, if the clearing is made during the dry season the migrated seeds do not develop until the wet one. This gives an opportunity for seeds to migrate before many germinate and therefore the first season shows vigorous weeds such as *Blumea balsamifera, Elephantopus mollis, Emilia flammea,* *E. sonchifolia, Adenostemma viscosum, Ageratum conyzoides, Triumfetta rhomboidea, Urena sinuata, Scoparia dulcis, Abutilon indicum, Sida carpinifolia, Commelina nudiflora, Solanum ferox, Hyptis suaveolens, H. spicigera, Euphorbia pilulifera,* and others. Among the vines are *Momordica charantia, Merremia hastata,* several species of *Ipomœa* and others. All are more or less rapidly growing, herbaceous forms with seeds adapted to easy distribution. During the dry season many of the above have partially disappeared.[27] Those which are left show a reduction of leaf surface, so that the thinness of the vegetation in these first stages is comparable with that of the tree vegetation of the *Bambusa-Parkia* formation. At this time a number of grasses also find a place. Among them may be mentioned *Panicum pilipes, P. sarmentosum, Oplismenus burmannii,* and *Centotheca lappacea. Imperata exaltata,* the principal cogon grass, gains an entrance more slowly, but after the first year it begins to give a decided aspect to the vegetation. This is due to the rapid development of underground shoots by means of which, from a common center, it can migrate in all directions, and soon establish a more or less dense sod which shades out other forms. With the appearance of the cogon there is initiated a new period which may be prolonged to a greater or less extent. If the soil is shallow, as is often the case on an exposed ridge where erosion is great, many of the more mesophytic forms, growing with the grass during the wet season, may not be able to survive the period of drought, and thus the encroachment of woody forms is slow. Nevertheless, if the periphery of the "cogonal" is the edge of a wooded area, the shade on the border may be sufficiently dense to make impossible the existence of the grass, although woody species which are not so light-demanding, may obtain a foothold. With each generation the shady periphery advances on the island of grass and in time replaces it.

Again, in more mesophytic places, a grass land once established offers a more or less favorable feeding place for cattle, carabaos, and horses. In order that the coarse grass may not become too woody, or for other reasons, the owners may burn the area periodically. Thus many ligneous species which may have started are killed, while the geophilous parts of the grass are uninjured. Hence, by repeated fires, cogonales are maintained indefinitely and even enlarged at the expense of the neighboring woody formation. As soon as the fires are checked, the invasion begins anew and in time the grass will be crowded out. The rapidity of the invasion of woody species depends on the nature of the surrounding vegetation and on the chresard of the soil. If the chresard is high, it will be rapid; if, as indicated above, it is low, then it will be slow. *Imperata exaltata* grows to the height of a meter or more. This altitude together with its more or less dense sod enables it successfully to compete with other grasses, but occasionally openings in the "parang" are found in which *Andropogon aciculatus,* which is propably a better forage grass than cogon, is present; this forms a carpet, but unlike the cogon it spreads by runners above ground instead of by root stalks. It does not grow to a great height and many instances were noted where it is being crowded out by the cogon. The *Andropogon* areas are never so extensively developed as the cogonales although patches of the former are often found in the latter. *Imperata arundinacea koenigii,* the smaller "cogon" grass, is also present in the grass lands, although it, like the *Andropogon* is not so successful as *I. exaltata.* While many other grasses are present, especially in the early stages of the development of the "cogonales," yet none are conspicuous numerically. The large bunch grass, *Saccharum spontaneum,* so characteristic of the lowlands in semi-hydrophytic conditions, is confined to individual specimens on the rocky flood plains of the rivers and to the abandoned rice lands near the mouth of the Alangan River.

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[27] The line between annual and perennial on the one hand and herbaceous and woody plants on the other can not be so closely drawn in the Tropics as in temperate regions. The life of the same plant may be prolonged in one situation over the dry season, while in others, less favorable, it dies down to the ground. Most of the plants mentioned in this list can spring from seed, and flower in one season. Usually the rapid growth is during the rainy season while at its close, reproductive activity sets in. Most of those having perennial root stalks become more or less woody and persistent and therefore can not strictly be called herbs.

Psidium parang.—The invasion into the cogonales of arboreal species, or into caingins, brings about the initial stages of temporary formation in which tree instead of grass species predominate. After the beginning "weed" stage the cogonal, as shown above, may intervene before the tree stage is reached, or if the conditions necessary for the cogonales are not obtained, the transition may be more or less direct. All the steps in the transition from the newly made caingin to the fully developed woody type have been observed. If the caingin is surrounded by a forest in which there are no exotic species, the seeds of the latter which enter will need to be blown by the wind or carried a long distance by birds and other animals. The chances are that none or but a few exotics will be present. Without exception, clearings observed in the *Anisoptera-Strombosia* forest had no exotic tree species. The surrounding forest or the closely lying open places furnish the seeds which are to develop into the plants which form the invading vegetation. The floristic composition will be discussed under a treatment of such clearings in connection with the *Anisoptera-Strombosia* formation.

As in the case of cuttings, the first "clearings" are made near the seacoast, or if inland, they may radiate from a common center (settlement) in one or more directions. When, finally, the clearing has been made and abandoned, as already described, it may pass through the cogonal stage; but if the conditions for the development of the latter are not present, then the arboreal one has an early beginning. The most common tree species found in these clearings and the first one to enter is

Psidium guajava (guava.) Blanco[28] to the contrary notwithstanding, this plant is believed to have been introduced from Mexico, its original home. The facts that it has no native name and that it is never found where the original vegetation has been undisturbed, certainly constitute strong evidence in favor of its exotic nature. The guava is well fitted for distribution. The edible, fleshy fruit is well filled with very small seeds which, when eaten by hogs, birds, etc., pass through the intestines undigested. In this way they may gain an early entrance into abandoned clearings. They are even found scattered through farms which are still in a state of cultivation. Such clearings early come to have a "guava" aspect. The tree sprouts freely, and if it is cut for fuel, new shoots are produced. Types of parang, which show no places where the vegetation has entirely been removed do not have the guava, but a partial removal of the vegetation intermixes the other types with that of the guava. Other species will also soon invade clearings from which all the vegetation has been removed, and then will join the guava in forming the new growth. In this way large tracts of land have come to be occupied by the guava mixed with the species of the other parangs. On the reserve there are all stages in the development of clearings. An enumeration of the species will be only a repetition of those already given. Groups of other cultivated trees which show the former condition are scattered through the guava parang. Thus isolated individuals or groups of *Mangifera indica* (mango), *Anacardium occidentale* (cashew), *Artocarpus integrifolia* (jack fruit), bananas, papaya, *Ceiba pentandra, Areca catechu,* and in one case *Cocos nucifera* were found scattered through the various stages in the development of a parang. Mention has already been made of the place in the vegetation of the building bamboo (*Bambusa blumeana*). No attempt has been made to enumerate all the indigenous species which were found. In spite of the detailed description of the different types, it is still felt that justice has not been done to the extreme floristic complexity of the vegetation.

Seasonal changes of the formation.—The aspect of the parang, like that of the *Bambusa-Parkia* forest, changes with the season. During the dry one many of the herbs die to the ground and all are much reduced in foliage. The trees show the result of drought and drop a portion of their foliage.

As a whole, the transpiration surface is decidedly thinner. While some of the trees flower irrespectively of season, yet the reproductive activity of a much larger number begins in May and continues through July. These three months are distinctly the flowering ones. Vegetative ac-

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[28] Blanco, M., Flora de Filipinas (1845), 292, claims that fossil forms of this plant have been found by the natives in volcanic rocks near Manila. He does not state that he has seen these plants himself. Brandis (See Forest Flora of India, 232) and others claim that it is certainly exotic in India and the Malayian region in general.

tivity may be present in all, but it is decidedly much more in evidence throughout the entire length of the wet season. During 3 or 4 months bamboo culms reach a height of from 12 to 15 meters, the shoots of trees develop rapidly, and herbaceous vegetation springs up with surprising quickness, the change from the dry to the wet season resembling to some extent the spring activity of vegetation in temperate regions.[29] Aside from the clothing of the trees with their full quota of leaves, the appearance of numerous herbs of various kinds decidedly changes the aspect of the vegetation. However, it is strikingly true that almost no herbs appear in the dense parang growth or in the bamboo forests, save here and there a few ferns, but on the edges of the clearings, in cogonales and, indeed, in any place where the vegetation is sufficiently thin to admit light to the ground, the latter is soon covered with various herbs. Among these, weeds such as *Hyptis, Triumfetta, Adenostemma,* etc. (see p. 396), are apt to form thickets on the edge of cogonales, where the shade of the surrounding tree vegetation is too great for the grasses. Among the first geophilous herbs is *Amorphophallus campanulatus.* About the middle of May, in places, in the thinner parts of the parang this species develops from a spherical corm, 15 to 20 centimeters in diameter, to an inflated spathe as large as one's head. Soon after the flower dies, a three-parted leaf with the segments pinnatified and with a spotted petiole appears. Often this reaches the height of 2 meters and is strikingly prominent in contrast with the surrounding vegetation. About the same time the flowers of *Curcuma zedoaria* and *Zingiber zerumbet* become apparent, to be followed by colonies of the canna-like leaves of the *Curcuma* and the pinnate ones of *Zingiber.* These are the most prominent of the geophilous herbs which frequently occupy large patches to the exclusion of all others. Cogonals which are brown in the dry season, rapidly turn green during the wet one, and in places where the grass is thin, many herbaceous plants or seedlings of arboreal species appear. In July, colonies of *Ophioglossum nudicaule,* or single individuals of *Helminthostachys zeylanica* among the ferms, grow in half open places on the edges of the parang or of the bamboo. By September these have disappeared. Prominent ferns, all but geophilous during the dry season, are *Hemionitis arifolia, H. gymnopterodea, Gymnopteris taccifolia, Polybotria apiifolia* and *Adiantum philippense. Cheilanthes tenuifolia* is xerophytic and tropophilous. *Anthoceros grandis* of the liverworts, prominent during the wet season on moist banks, and a few mosses are all which were noted of the *Bryophytes.*

Epiphytes.—The epiphytic vegetation, although not well studied, shows a scarcity of species in comparison with the formations higher up the mountain. The evergreen species of the parasitic *Loranthaceæ* which are found on the limbs of *Parkia roxburghii* (Pl. III) and on other species are, however, very striking. These are prominent features of the sky line when the foliage of the trees is thin. Very common also, in open places, on the trunks of trees, on rocks, and on fallen logs, is the deciduous epiphytic fern, *Drynaria quercifolia.* During the favorable season it has dimorphic leaves. During the dry season, the foliage leaf is shed and the scale leaf becomes dry and brown, strikingly showing the effect of the change of seasons on the formation in which it grows. A few epiphytic orchids were noted and were collected, but as the species as yet have not been determined the list can not be given here. The twining asclepidaceous epiphytic *Dischidia pectenoides* is usually found growing on bamboo near the upper limits of the formation. Besides the ordinary leaves, it has bladder-like ones which generally harbor insects and in which delicate roots are developed.

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[29] However, it must not be overlooked that many trees show vegetative as well as reproductive activity during the period of low chresard. This is especially the case with plants growing on the edges of water courses, where the chresard is more uniform throughout the year.

Relation of the vegetation to the topography.—In the preceding discussion some mention has been made of the varying types of vegetation in different physiographic situations. With the exception of the land lying close to the river, the physiographic types are ridges, slopes of ridges and old river terraces at or near their bases. Except when the latter are of such recent origin that the underground water level is near the surface, they do not offer any strikingly different habitat for plants than the more gentle slopes. The terrace appearance is often destroyed by the surface wash of the slopes and thus it grades imperceptibly into the latter and becomes a part of it. The river is young, so that as yet there have not been developed any flood plains, although during the rainy season the lowest terraces are flooded. The vegetation of these and of the river channel itself will be considered in another place. On the exposed ridges the vegetation is slightly more xerophytic than it is on the slopes, and here its composition is similar to that of the parang.

Future possibilities of the parang vegetation.—Since the parang is not peculiar to the Lamao Reserve, but is found throughout the Philippines, it is of considerable importance to ascertain what its forestal and agricultural possibilities are, and whether, in case it is left idle, it will again return to its normal condition. As long ago as 1880 Vidal[30] called attention to the idle nature of these lands and then he advocated their agricultural possibilities. No doubt much of the land is available for agriculture, but that portion which is situated on the slopes is better suited for purposes of forestry. Outside the reserve, on many mountain sides, the parang or cogonales extend well up on slopes which formerly were covered with virgin forests. The latter acted as better retainers of moisture than does the present vegetation and with the advent of a more intense agriculture at their bases, if they are returned to their original

[30] L. c., p. 10.

condition, they will be not only the future source of a timber supply but they will be the best conservers of water for irrigating purposes.

There is evidence to show that without the aid of man much of the "mixed" parang of the Lamao Reserve is returning to the original condition of the dicotyledinous portion of the *Bambusa-Parkia* formation. However, this does not include the bamboo portion of the formation. To understand the reason for this, it is necessary to know something of the seeding habits of this class of plants. It is obvious that, vegetatively, the "bunch" bamboos can not spread in such a manner as to occupy new territory, therefore, this type is wholly dependent on seeds for its distribution. With the exception of the climbing bamboo, *Dinochloa*, none of the bamboos of the Philippines have been collected in seed, and therefore it is apparent that the capacity of the "bunch" bamboos to spread from seed has not come under observation. The evidence furnished by British Indian foresters throws some light on the reproductive habits of this variety of vegetation. Kurz[31] is authority for the statement that a number of bamboos flower simultaneously after a lapse of years and then die. Brandis[32] states that isolated flowering clumps of *Bambusa arundinacea* are occasionally found, but as a rule, clumps in one flowering district come under flower simultaneously while a few may be found earlier and some in the following year. This author[33] further says that *Bambusa polymorpha* in 1859 flowered and then died, in a forest of this bamboo found in Pegu under tall trees of *Xylia dolabriformis*, *Terminalia tomentosa*, *Tectona grandis* (teak), and others. In 1861 there were many millions of seedlings. Only when a year of bamboo seeding takes place can suppressed young teak obtain a foothold or do teak seedlings appear. While there is no authentic record of the bamboo of the Lamao Forest Reserve or any of the common clump species of the Philippines having flowered yet, according to the authority of the natives, these species behave in much the same manner as do those described by Brandis and other Indian foresters. It may not be out of place to predict that in case the bamboo called "boho" by the natives, flowers simultaneously at more or less regular periods, then there may be a decided subsequent change in the aspect of the *Bambusa-Parkia* forests. If the older stalks die down at the time of the flowering of these bamboos, then the park-like nature of the dicotyledinous growth will become very apparent. Practically, then, there will be a new habitat to which light will have access. The suppressed dicotyledinous trees will spring up more rapidly, the ground will be freely occupied by *Bambusa* seedlings and by the sprouts of dicotyledinous trees which had seeds available at the time of the death of the bamboo. Then a struggle will begin between the seedlings of various kinds and the saplings and young trees already present. Many of these latter no doubt will hold their own and will occupy a place in the new, matured forest which will be developed. Owing to the rapidity of the growth of the bamboo seedlings, but few of the dicotyledinous seedlings will be able to compete successfully with them. Attention also should be called to the fact that according to the observations of Indian foresters, from the seed it takes from eight to ten years for the culms of *Bambusa arundinacea* to reach full size. No doubt a number of years would elapse before the culms of "boho" could reach their ultimate height of from 15 to 18 meters. If such be the case, this period of maturity would be sufficiently long to permit the young trees and saplings to gain considerable headway in a young forest of bamboo. Thus, as the bamboo growth reaches maturity, the dicotyledinous trees present, but which previously had been suppressed, will also reach maturity and the new forest which is thus developed will in many respects resemble the original one which it replaces. Kurz [34] is also authority for the statement that where bamboo growth in the original forest has taken place around clearings or what would correspond to cogonales, these bamboo seedlings soon spring up and choke out all other vegetation except that of light-loving, quick-growing sapling trees. If this should become the case on the Lamao Forest Reserve, then portions at least of the cogonales will be captured by the bamboo growth. Whether the bamboo seedlings will be able successfully to survive or even whether the seeds will germinate at all under the tolerable dense shade of the forest types of parang growth, remains to be demonstrated. It is not likely that many seedlings will be able to exist under such conditions. It must be understood that what is said represents only a conjecture. Extensive observation on the spot is needed to demonstrate the actual behavior of the bamboo when it seeds.

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[31] Curz, S., *Forest Flora of British Burma*, **1:** (1877) Introd., p. XXIX.

[32] Brandis, D., Flowering of *Bambusa arundinacea Ind. For.* **13:** 509.

[33] Biological Notes on Indian Bamboos. *Ind. For.* (1899) **25:** 1 to 25.

As I have already mentioned, there is evidence to show that the dicotyledinous trees of the original growth of the *Bambusa-Parkia* formation are gradually encroaching on the parang, especially at its thinner portions and into the cogonales themselves. Many instances were noted where seedlings were starting in the semi-shaded area produced by the woody growth of the periphery of the cogonales. Where the parang borders on the grass areas, then the species which are thus introduced are rather more generally those of the parang than of the original growth. Nevertheless, if the parang is in the neighborhood of seeding trees of the latter class, or if these trees be in the parang itself, there will be developed some seedlings. After a number of years at least some of the latter will overtop the low growth of the parang, causing it to become more or less suppressed, and it therefore will be reduced to a subordinate place in the new forest thus established. Many instances were noted where such alterations were taking place. Of course, the new forest would almost entirely be a dicotyledinous one unless, during some stage of its development, the bamboos in the neighborhood should seed and find an entrance into it. The areas of the parang situated at some distance from the original forest would in all likelihood not be stocked with seeds from the former and thus the forest in these places would need to pass through a number of generations of growth, each successive one approaching nearer to these distant areas, before the latter could be reclaimed.

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[34] L. c., Introd., p. xxx.

Summary.—1. The *Bambusa-Parkia* formation occupies the region of the Lamao Forest Reserve at the base of the mountain. It is divided into two types, i. e., the climax and the parang. The former type occupies the upper portion of the formation, but has islands lower down and peninsulas extending nearly to the sea. Its area is approximately one-third of the entire formation. The latter has tongues extending into the former. It occupies approximately two-thirds of the entire formation. In this type are included the cogonales.

2. All species in the parang except *Psidium guajava* are represented by suppressed forms in the climax type, or they are prominent forms which are there reduced to the coppice condition. Xerophytic areas of the climax type (like exposed ridges or ends of ridges) resemble parang forms.

3. If left undisturbed, parang types will gradually return to the climax, with or without the bamboo.

4. The parang type includes:

Cogonales.
Psidium parang.
Dinochloa parang.
Lagerstrœmia-Zizyphus parang.
Streblus-Aphananthe parang.
Mixed parang.

5. The climax forest is closely related to Schimper's [35] monsoon tropical forest or Kurz's [36] mixed tropical forest.

6. The *Bambusa-Parkia* formation, in contrast with the forest higher up the slopes of the mountain, is more xerophytic. This is due to less rainfall, lower relative humidity and greater heat.

7. The xerophytic nature of this formation finds expression in deciduous and partially deciduous trees, in semi-xerophytic structures, evergreen trees, and in geophilous or semi-geophilous herbs.

II. ANISOPTERA-STROMBOSIA FORMATION.

This formation lies immediately above the *Bambusa-Parkia* forest. *Anisoptera vidaliana* (mayapis) is representative of the largest tree species in which *Dipterocarpaceæ* predominate. *Strombosia philippinensis* is the principal tree of the second story and stands for a group having a place in this forest similar to that occupied by the bamboo in the *Bambusa-Parkia* formation. Indeed, on the border between the two there is a mixture of this element with the bamboo; for both together, or islands of one surrounded by the other, prevail as a second-story vegetation.

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[35] L. c., 352.

[36] L. c. Introd., p. XXV.

FORESTS OF RIVER TERRACES.

Much has been written concerning the floristic composition of a tropical forest. Lists of tree species have been made which show the number of species, but so far as is known there exists no quantitative analysis of a tropical forest.[37] The following tables will give some idea of the complexity of the forests of the Lamao Reserve.

Description of Table XIII.

The plot is on a low, rocky, narrow terrace of Lamao River at an altitude of 100 meters. It comprises an area of approximately 8,000 square meters. A gives the number of trees over 4 meters in height; second line under this heading, the number under 4 meters in height, including seedlings; B, the percentage of each species, and C, the percentage of trees of each species in the adjoining hillside plot. (See next table.)

TABLE XIII.

Name of plant	A.	B.	C.
1. Anisoptera vidaliana	28 25	8.3	2.10
2. Mangifera altissima	24 35	7.0	.11
3. Lagerstrœmia speciosa	14	4.1	.22
4. Eugenia luzonensis	11 7	3.3	-----
5. Palaquium luzoniense	11 2	3.3	1.22
6. Calophyllum wallichianum	10 8	2.9	.77
7. Phæanthus cumingii	9 8	2.6	1.00
8. Bischofia trifoliata	8	2.31	
9. Canarium villosum	8 2	2.31	
10. Gnetum gnenom	8 4	2.31	7.74
11. Diospyros pilosanthera	7 26	2.02	4.64
12. Pandanus luzonensis	7 Many.	2.02	.44
13. Parkia roxburghii	7 Many.	2.02	.55
14. Pithecolobium acle	7 2	2.02	
15. Dysoxylum cumingianum	6 6	1.73	.11
16. Baccaurea tetrandra	6 10	1.73	1.19
17. Koordersiodendron pinnatum	6 14	1.73	1.11

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[37] The writer has not had access to all the literature on the subject.

TABLE XIII—Continued.

Name of plant.	A	B.	C.
18. Leea manillensis	6 40	1.73	
19. Reinwardtiodendron merrillii	6 43	1.73	3.21
20. Dipterocarpus vernicifluus	5 12	1.44	2.21
21. Shorea contorta	5	1.44	2.65
22. Zizyphus zonulatus	4	1.15	
23. Cratoxylon blancoi	4 1	1.15	
24. Dracontomelum cumingianum	4 1	1.15	33
25. Knema heterophylla	4 3	1 15	1.11
26. Memecylon edule	4 7	1.15	1.11
27. Shorea guiso	4 6	1.15	3.43
28. Strombosia philippinensis	4 13	1.15	10.50
29. Tabernæmontana pandacaqui	4 14	1.15	.44
30. Celtis philippinensis	3 1	.86	.88
31. Cyclostemon bordenii	3 10	.86	2.88
32. Cynometra simplicifolia	3 1	.86	.33
33. Dracæna angustifolia	3 11	.86	.22
34. Ellipanthus luzoniensis	3	.86	.66
35. Eugenia bordenii	3 6	.86	.55
36. Ficus hauili	3 4	.86	.44
37. Kayea paniculata	3 2	.86	
38. Kleinhofia hospita	3	.86	
39. Pterospermun niveum	3 5	.86	
40. Radermachera banaibana	3	.86	.22
41. Sarcocephalus cordatus	3	.86	
42. Turpinia pomifera	3	.86	2.10
43. Cryptocarya luzoniensis	3 5	.86	1.00
44. Linociera coriacea	3	.86	.55
45. Aglaia harmsiana	2	.57	2.32
46. Artocarpus communis	2	.57	.11
47. Champereia cumingiana	2	.57	1.44
48. Chisocheton tetrapetalus	2	.57	1.33
49. Cyathocalyx globosus	2	.57	.55
50. Cyclostemon microphyllus	2	.57	.11

TABLE XIII—Continued.

Name of plant.	A.	B.	C.
51. Eugenia sp	2	.57	
52. Euphoria cinerea	2	.57	1.88
53. Ficus caulocarpa	2	.57	
54. Glochidion album	2	.57	
55. Grewia stylocarpa	2	.57	.77
56. Leea philippinensis	2	.57	.55
57. Terminalia nitens	2	.57	
58. Sp. indet	2	.57	.11
59. Aglaia turczaninowii	1	.29	
60. Aphananthe philippinensis	1	.29	.66
61. Artocarpus lanceolata	1	.29	.33
62. Buchanania florida	1	.29	.22
63. Canangium odoratum	1	.29	
64. Casearia fuliginosa	1	.29	.44
65. Citrus hystrix	1	.29	
66. Elæocarpus oblongus	1	.29	
67. Eugenia acuminatissima	1	.29	
68. Ficus pseudopalma	1	.29	
69. Ficus paucinervia	1	.29	
70. Ficus sp	1	.29	
71. Ficus sp	1	.29	
72. Ficus sp	1	.29	
73. Garcinia binucao	1	.29	.55
74. Guioa perrottetii	1	.29	
75. Leucosyke capitellata	1	.29	
76. Neolitsea vidalii	1	.29	.11
77. Macaranga tanarius	1	.29	
78. Myristica philippensis	1	.29	.66
79. Palaquium tenuipetiolatum	1	.29	1.22
80. Palaquium whitfordii	1	.29	
81. Polyalthia barnesii	1	.29	.66
82. Polysias nodosa	1	.29	.22
83. Pterospermum diversifolium	1	.29	.33

TABLE XIII—Continued.

Name of plant.	A.	B.	C.
84. Pterospermum obliquum	1	.29	.44
85. Pygeum latifolium	1	.29	.22
86. Sideroxylon macranthum	1	.29	.22
87. Spondias mangifera	1	.29	
88. Talauma villariana	1	.29	1.19
89. Xanthophyllum sp	1	.29	1.66
90. Sp. indet	1	.29	
91. Sp. indet	1	.29	
92. Sp. indet	1	.29	
Total	328		

Relation of vegetation to topography.—As previously stated, the Lamao River is distinctly an eroding one. At the altitude of the above plot there is a fall of 7 in a total distance of 300 meters; at high water the stream floods some portions of the terrace and maintains one prominent channel through it. This leaves the terrace divided into two parts; one, which is made up of large boulders, is from 2 to 2½ meters above the river and stands between it and the flooded channel; the other, somewhat higher, lies at the base of the adjoining hill, and though it contains some boulders, yet these are more or less covered with surface wash from the slopes of the hill. A very small amount of silt is deposited between the rocks in extreme floods, when nearly all of the boulder terrace is under water for a short time. The absence of much soil and the periodic presence of a swift current make it a difficult place for plants to gain a foothold, consequently the vegetation is more or less open.

The wet-weather channel is more or less destitute of vegetation during the rainy season because of the swift currents periodically sweeping through it. During the dry one, many young plants of *Pandanus luzonensis, Eugenia luzonensis,* and others spring up, only to be to a great extent washed out during the following wet period. The vegetation on the boulder flood-plain is very much like that encountered in some portions of the *Bambusa-Parkia* formation. *Anisoptera vidaliana, Lagerstrœmia speciosa, Dracontomelum cumingianum, Parkia roxburghii, Cananium villosum,* and *Zizyphus zonulatus* are here present.

On the borders of the wet-weather channel and of the stream *Eugenia luzonensis, Bischofia trifoliata, Sarcocephalus cordatus,* and *Kleinhofia hospita* (Pl. VI) are characteristic and, so far as the Lamao Reserve is concerned, are found in no other ecological situation. The terrace at the foot of the hill shows a condition similar to that on the adjoining slopes. A reference to the table will make apparent the relative proportion of species to be found in the entire plot and on that of the hillside. *Mangifera altissima* is the only species on the less boulder-like terrace which is not also common on the hillside.

Because of the park-like nature of the entire terrace, the underbrush is here more common than it is in the more closed forest about to be described. The shrubby species which are common and characteristic of the river bottom are *Lunasia amara, Justicia gendarussa, Glochidion sp.*, many seedlings of *Pandanus luzonensis*, jungle-like thickets of *Donax arundastrum*, and a few clumps of *Bambusa lumanpao.* Among the herbaceous forms are *Hypœstis cinerea, Clerodendron intermedium*, and *Alpinia brevilabris.* The following ferns are also found here: *Microlepia speluncæ, Gymnopteris contaminans, Lygodium circinatum Polypodium myriocarpum*, growing on rocks and on the base of trees, and *Pteris cretica.* A number of grasses are common in the open places.

Epiphytes.—The epiphytic vegetation is probably more prominent than observations show. The difficulty of obtaining a good idea of the character of the tops of the trees is great. However, a number of epiphytic orchids were obtained from tall trees by the natives and some were found on low branches in places having sufficient light. These include five species only. The epiphytic fern *Drynaria quercifolia* grows in open places on the trunks or branches of trees.

Lianas.—The liana vegetation is very characteristic. Because of the excess of light, the vines are encountered not only in the tops of the trees but in places they even form dense walls on the open sides of the more closed areas. *Symphorema luzonicum* is perhaps the most characteristic of this vegetation and its habit may be taken as a type of that of all of the larger vines. Growing as it does to the tops of the large trees, by its own weight it may drag lower portions of its own length to the ground so that it may lie recumbent. From these parts in the denser shade new shoots may arise. These often remain suppressed until a natural opening will give them an opportunity for rapid development. Thus the new shoots may trail to a greater or less extent until a support is reached, after which they become erect and in time will grow to the tops of the trees. Often, the prostrate portion becomes covered with earth, so that the shoots arising from it resemble young trees starting in the dense shade of the forest. During the wet season and growing in the dense shade, the long, etiolated, leafless shoots of the *Gnetum latifolium* (another common liana) resemble saprophytic plants so nearly that one is easily deceived concerning their true nature. Indeed, such shoots are in one sense saprophytic, for when they grow in a situation where the light is insufficient to enable them to elaborate their own food, they are dependent upon the foliage at the tops of the tall trees for their nourishment. Often three or more vines are found on a single tree. One instance emphasizing this fact was noted where *Symphorema* *luzonicum, Gnetum latifolium, Pothos philippinensis, Pothoidium lobbianum, Freycenetia luzonensis,* and the large leaved *Conocephalus violaceus* were growing on the same individual. Among the other large lianas noted were *Strychnos multiflora, Tetracera sarmentosa, Dinochloa diffusa, Ficus bordenii, Anamirta cocculus, Combretum squamosum, Cnestis ramiflora,* five species of *Calamus, Stixis philippinensis, Rivea luzonensis,* species of *Cissus, Mucuna imbricata, Dioscorea pentaphylla,* and others. Some idea will be given of the character of the vegetation by the three photographs taken in or near the plot in consideration. (Pls. VI, VII, VIII.)

The character of the vegetation on terraces similar to that already described, but the boulders lying in which are to a greater extent covered by the wash of the adjoining slopes and which usually are slightly higher in situation, is shown by Plates IX, X, XI, and XII.

FORESTS OF SLOPES.

Description of Table XIV.

The plot classified in the following table is on the hillside, extending up the slopes at right angles to the one on the river valley terrace (See Table XIII). It is approximately 60 meters in width and 170 meters in length. The area thus contains 10,200 square meters. The gradient averages about 27 degrees, but in places it is as much as 40 degrees, and for a short distance halfway up the hill it is nearly level. The plot is divided into 5 subplots roughly corresponding to 15-meter contour lines. Beginning at A, the plot runs uphill to E. The column F gives the total number of trees over 4 meters in height in all the plots, and G the total number under 4 meters. H gives the percentage of each species, and I the percentage of species in the river terrace plot (see Table XIII).

TABLE XIV.

Name.	A.	B.	C.	D.	E.	F.	G.	H.	I.
1. Strombosia philippinensis	10	13	24	27	20	94	------	10.50	1.15
	9	13	45	13	33	------	113		
2. Gnetum gnemon	3	3	12	15	37	70	------	7.74	2.31
	------	4	3	2	9	------	18		
3. Diospyros pilosanthera	3	5	11	11	12	42	------	4.64	2.02
	3	8	20	25	24	------	80		
4. Aporosa symplocosifolia	------	1	5	2	30	38	------	4.20	------
	1	4	5	3	15	------	28		
5. Shorea guiso	2	6	13	6	4	31	------	3.43	1.15
	1	1	30	24	20	------	76		
6. Reinwardtiodendron merrillii	8	14	5	2	------	29	------	3.21	1.73
	27	8	22	9	2	------	68		
7. Cyclostemon bordenii	6	6	8	3	3	26	------	2.88	.86
	8	21	16	19	9	------	73		
8. Shorea contorta	2	1	11	5	5	24	------	2.65	1.44
	3	------	4	3	2	------	12		
9. Aglaia harmsiana	3	6	2	4	6	21	------	2.32	.57
	2	5	6	8	14	------	35		
10. Dipterocarpus vernicifluus	4	3	11	1	1	20	------	2.21	1.44
	10	20	15	7	------	------	52		
11. Anisoptera vidaliana	1	2	4	8	4	19	------	2.10	8.30
	------	1	4	3	2	------	10		
12. Turpinia pomifera	------	1	1	9	8	19	------	2.10	.86
	------	1	1	2	3	------	7		

TABLE XIV—Continued.

Name.	A.	B.	C.	D.	E.	F.	G.	H.	I.
13. Baccaurea tetrandra	------ 3	4 2	7 14	4 15	3 6	18 ------	------ 40	1.19	1.73
14. Talauma villariana	------ ------	5 2	7 2	3 5	3 ------	18 ------	------ 9	1.19	.29
15. Euphoria cinerea	2 10	3 8	6 5	3 11	3 9	17 ------	------ 43	1.88	.57
16. Xanthophyllum sp	5 ------	3 1	4 8	1 7	2 4	15 ------	------ 20	1.66	.29
17. Antidesma edule	1 2	------ 1	10 3	------ 3	2 1	13 ------	------ 10	1.44	------
18. Champereia cumingiana	1 ------	------ ------	2 3	4 ------	6 3	13 ------	------ 6	1.44	.57
19. Chisocheton tetrapetalus	------ 1	4 12	4 1	3 5	1 5	12 ------	------ 24	1.33	.57
20. Atalantia disticha	1 1	------ 1	------ 1	------ 2	10 35	11 ------	------ 40	1.22	------
21. Palaquium luzoniense	1 1	2 ------	1 1	4 5	3 4	11 ------	------ 11	1.22	3.30
22. Santiria nitida	------ ------	------ ------	3 2	1 3	7 3	11 ------	------ 8	1.22	------
23. Palaquium tenuipetiolatum	------ ------	1 2	6 2	3 1	1 2	11 ------	------ 7	1.22	.29
24. Dimorphocalyx longipes	------ ------	------ ------	------ ------	2 ------	9 10	11 ------	------ 10	1.22	------
25. Memecylon edule	------ ------	2 4	3 7	1 3	4 27	10 ------	------ 41	1.11	1.15
26. Knema heterophylla	1 3	2 1	2 3	2 4	3 ------	10 ------	------ 11	1.11	1.15
27. Koordersiodendron pinnatum	------ ------	1 1	4 4	1 1	4 1	10 ------	------ 7	1.11	1.73
28. Phaeanthus cumingii	5 10	------ 1	------ 3	1 3	3 2	9 ------	------ 19	1	2.60
29. Cryptocarya luzoniensis	3 1	------ 1	3 ------	1 2	2 6	9 ------	------ 10	1	.86
30. Celtis philippinensis	1 2	------ 6	1 9	2 2	4 5	8 ------	------ 24	.88	.86
31. Mitrephora ferruginea	1 ------	5 3	------ ------	2 ------	------ 1	8 ------	------ 4	.88	------
32. Calophyllum wallichianum	2 15	1 25	3 27	1 26	------ 12	7 ------	------ 105	.77	2.90
33. Grewia stylocarpa	2 2	1 7	3 4	1 11	------ 5	7 ------	------ 29	.77	.57
34. Xylopia dehiscens	1 ------	------ ------	2 5	------ 1	3 16	6 ------	------ 22	.66	------
35. Polyalthia barnesii	------ 2	------ 4	2 5	3 5	1 1	6 ------	------ 17	.66	.29
36. Ellipanthus luzoniensis	------ 4	2 1	2 3	2 1	------ 2	6 ------	------ 11	.66	.86
37. Macaranga mappa	------ ------	4 1	------ ------	1 ------	1 2	6 ------	------ 3	.66	------
38. Aphananthe philippinensis	4 ------	1 ------	1 ------	------ ------	------ ------	6 ------	------ ------	.66	.29
39. Myristica philippensis	2 ------	------ ------	------ ------	2 ------	2 ------	6 ------	------ ------	.66	.29
40. Garcinia binucao	------ 5	------ 6	1 25	3 25	1 7	5 ------	------ 68	.55	.29
41. Eugenia bordenii	2 2	------ 3	2 12	------ 2	1 4	5 ------	------ 23	.55	.86
42. Leea philippinensis	1 1	1 ------	------ 1	1 4	2 2	5 ------	------ 8	.55	.57
43. Linociera coriacea	1 1	1 2	1 1	1 1	1 3	5 ------	------ 8	.55	.86
44. Cyathocalyx globosus	------ ------	1 2	3 5	1 ------	------ ------	5 ------	------ 7	.55	.57
45. Polyalthia flava	------ 1	------ ------	1 ------	1 ------	3 1	5 ------	------ 2	.55	------

TABLE XIV—Continued.

Name.	A.	B.	C.	D.	E.	F.	G.	H.	I.
46. Parkia roxburghii	3 ----	2 1	---- ----	---- ----	---- ----	5 ----	---- 1	.55	2.02
47. Alstonia scholaris	---- ----	1 ----	2 ----	1 ----	1 ----	5 ----	---- ----	.55	----
48. Hopea acuminata	---- ----	1 ----	2 2	1 1	1 ----	5 ----	---- 3	.55	----
49. Tabernæmontana pandacaqui	---- 9	---- 10	2 9	---- 5	2 26	4 ----	---- 59	.44	1.15
50. Ixora cumingii	---- 1	1 9	---- 9	---- 1	3 20	4 ----	---- 40	.44	----
51. Antidesma leptocladum	---- ----	---- 3	1 5	---- 2	3 ----	4 ----	---- 10	.44	----
52. Pterospermun obliquum	---- ----	---- ----	---- 1	2 2	2 6	4 ----	---- 9	.44	.29
53. Aglaia bordenii	---- 1	---- 3	1 3	1 2	2 2	4 ----	---- 11	.44	----
54. Clausena anisum-olens	---- ----	---- ----	---- 2	---- ----	4 3	4 ----	---- 5	.44	----
55. Casearia fuliginosa	1 ----	---- 3	1 1	2 ----	---- ----	4 ----	---- 4	.44	.29
56. Sterculia oblongata	1 ----	---- ----	---- ----	1 2	2 1	4 ----	---- 3	.44	----
57. Sp. indet	2 ----	---- ----	2 3	---- ----	---- ----	4 ----	---- 3	.44	----
58. Plectronia umbellata	---- ----	---- ----	---- ----	---- ----	4 1	4 ----	---- 1	.44	----
59. Ficus hauili	---- ----	2 ----	2 ----	---- ----	---- ----	4 ----	---- ----	.44	.86
60. Pandanus luzonensis	---- ----	---- ----	---- ----	4 ----	---- ----	4 ----	---- ----	.44	2.02
61. Cynometra simplicifolia	2 1	---- 1	---- ----	1 1	---- 4	3 ----	---- 7	.33	.86
62. Semecarpus perrottetii	---- ----	---- ----	1 4	1 3	1 ----	3 ----	---- 7	.33	----
63. Pterospermum diversifolium	---- ----	---- ----	---- 1	3 5	---- ----	3 ----	---- 6	.33	.29
64. Sp. indet	1 ----	---- ----	---- 1	1 ----	1 2	3 ----	---- 3	.33	----
65. Diospyros nitida	---- ----	---- ----	1 ----	---- ----	2 2	3 ----	---- 2	.33	----
66. Illipe ramiflora	---- ----	---- ----	1 2	2 ----	---- ----	3 ----	---- 2	.33	----
67. Linociera cumingiana	---- ----	---- 1	---- 1	---- ----	3 ----	3 ----	---- 2	.33	----
68. Artocarpus lanceolatus	1 ----	1 ----	---- ----	---- ----	1 ----	3 ----	---- ----	.33	.29
69. Dracontomelum cumingianum	3 ----	---- ----	---- ----	---- ----	---- ----	3 ----	---- ----	.33	1.15
70. Shorea polysperma	---- ----	---- ----	2 ----	1 ----	---- ----	3 ----	---- ----	.33	----
71. Litsea luzonica	---- 2	---- 5	---- 13	1 6	1 3	2 ----	---- 29	.22	----
72. Mitrephora lanotan	---- 5	---- 1	1 6	---- 3	1 4	2 ----	---- 19	.22	----
73. Dracæna angustifolia	---- 1	---- 2	---- 2	1 5	1 6	2 ----	---- 16	.22	.86
74. Cinnamomum mercadoi	---- ----	---- ----	---- ----	---- ----	2 2	2 ----	---- 2	.22	----
75. Euphorbiaceæ sp	1 ----	---- ----	1 ----	---- ----	---- 1	2 ----	---- 1	.22	----
76. Buchanania florida	---- ----	---- ----	---- ----	---- ----	2 ----	2 ----	---- ----	.22	.29
77. Crypteronia cumingii	---- ----	---- ----	2 ----	---- ----	---- ----	2 ----	---- ----	.22	----
78. Gonocaryum tarlacense	1 ----	---- ----	1 ----	---- ----	---- ----	2 ----	---- ----	.22	----

TABLE XIV—Continued.

Name.	A.	B.	C.	D.	E.	F.	G.	H.	I.
79. Lagerstrœmia speciosa	1			1		2		.22	4.10
80. Palaquium oleiferum			1		1	2		.22	
81. Polysias nodosa	1		1			2		.22	.29
82. Pterocymbium tinctorium				2		2		.22	
	1						1		
83. Pygeum latifolium					2	2		.22	.29
84. Radermachera banaibana				2		2		.22	.86
85. Sp. indet			1	1		2		.22	
86. Cyclostemon microphyllum				1		1		.11	.57
	1	4	6	12	9		32		
87. Garcinia venulosa			1			1		.11	
	1	2	3	1			7		
88. Neolitsea vidalii			1			1		.11	.29
			1	5			6		
89. Sideroxylon macranthum			1			1		.11	.29
				5			5		
90. Dysoxylum cumingianum	1					1		.11	1.73
	2		1	2			5		
91. Sideroxylon duclitan	1					1		.11	
		1	2	2			5		
92. Unona clusiflora					1	1		.11	
	1		1	3			5		
93. Endiandra coriacea					1	1		.11	
	1				1		2		
94. Flacourtia inermis					1	1		.11	
					2		2		
95. Parinarium griffithianum					1	1		.11	
				1	1		1		
96. Plectronia sp					1	1		.11	
					2		2		
97. Pahudia rhomboidea					1	1		.11	
					1		1		
98. Ixora sp				1		1		.11	
		1					1		
99. Sp. indet					1	1		.11	
					1		1		
100. Sp. indet		1				1		.11	.57
			1				1		
101. Artocarpus communis		1				1		.11	.57
102. Dipterocarpus grandiflorus			1			1		.11	
103. Ficus ampelas			1			1		.11	
104. Ficus sp			1			1		.11	
105. Ficus nota	1					1		.11	
106. Ficus variegata			1			1		.11	
107. Ganophyllum obliquum				1		1		.11	
108. Gardenia barnesii					1	1		.11	
109. Mallotus ricinoides		1				1		.11	
110. Mangifera altissima	1					1		.11	7.00
111. Planchonia spectabilis			1			1		.11	

TABLE XIV—Continued.

Name.	A.	B.	C.	D.	E.	F.	G.	H.	I.
112. Sterculia crassiramea				1		1		.11	
113. Vitex sp			1			1		.11	
114. Randia fitzalani			1			1		.11	
115. Sp. indet	1					1		.11	
116. Sp. indet	1					1		.11	
117. Sp. indet			1			1		.11	
118. Sp. indet				1		1		.11	
119. Sp. indet					1	1		.11	
120. Sp. indet					1	1		.11	
Total						896			

Storied vegetation.—An analysis of this plot, as a whole, more or less strikingly shows two stories of vegetation. In the upper one, the trees reach to the height of 25 to 36 meters. (See Pl. XII.) The species composing it are, in the main, *Dipterocarpaceæ.* Among these are *Shorea guiso* (guijo), *Shorea contorta,* (lauan) *Dipterocarpus vernicifluus* (panao), *Anisoptera vidaliana* (mayapis), *Shorea polysperma* (tanguili), and *Hopea acuminata* (dalindingin). Still others in the upper story are *Euphoria cinerea, Santira nitida, Palaquium luzoniense, P. tenuipetiolatum,* and *Koordersiodendron pinnatum.* In all, about 31 species, out of a total of 121 found in the plot, have representatives in the upper story.

A careful analysis of the plot will, in places at least, show that the trees of the top story are far apart. (Pl. XII.) While the crowns for a short distance are often close enough together to make an even skyline yet there are often depressions in this profile which are due to the absence of the upper-story trees. However, this irregularity is not so striking as it is in the *Bambusa-Parkia* formation. The lower-story vegetation consists of the younger trees of the upper one, together with species which seldom reach 20 meters and usually are from 10 to 15 meters in height. (Pls. XIV, XV.) Of these the most common are *Strombosia philippinensis, Gnetum gnemon, Diospyros pilosanthera, Aporosa symplocosifolia, Reinwardtiodendron merrillii,* and others.

Relation to topography.—The table shows differences in vegetation corresponding to types of topography. In Plots A and E the gradient is near 40 degrees, and corresponding to this, there are fewer tall trees and many more saplings and seedlings. E is on the brow of the hill, and much more exposed to winds, the soil is shallower and stony, and no doubt the chresard is much lower. Less mesophytic species such as

Atalantia disticha, Memecylon edule, Dimorphocalyx longipes, Xylopia dehiscens, Tabernæmontana pandacaqui, and *Ixora cumingii* are found at the extreme upper limits of the plot and with others in the adjacent territory very much resemble the low parang vegetation. Indeed, the entire brow of the hill is covered with the tangled growth of the climbing bamboo, *Dinochloa diffusa.* Of the mesophytic species *Strombosia philippinensis* and *Gnetum gnemon* are representative. While they are prominent in the subplot E, yet they occupy the lower half of it. (See Pl. XV.) As a rule the *Dipterocarpaceæ* are found to be best developed in Plots C. and D. Here the slope is more gentle.

A comparison of the entire hillside with the river terrace shows differences other than those which have been mentioned. *Anisoptera vidaliana,* occupying first place in the river terrace, stands eleventh on the hillside. *Palaquium luzoniense* is very common below, but it is represented only by a few scattered specimens above. A reference to columns H and I of Table XIV and B and C of Table XIII will strikingly show these differences. To give a better idea of the complexity of the floristic composition of the forest and of the differences due to physiographic situations, six other plots were made in this *Anisoptera-Strombosia* formation.

Description of Table XV.

This table classifies plots in various physiographic situations of the *Anisoptera-Strombosia* formation. A, forest on a slope of 10 to 12° gradient at an altitude of 100 meters. The plot comprises an area of 1500 square meters. B, forest on a terraced island at an altitude of 80 meters. This terrace is under water for a very short time at extremely high floods. The plot comprises an area of 600 square meters. C, plot in the river terrace a little higher than B. It is near the mouth of a wet-weather stream and is flooded at the highest water. It is near Plot A and comprises about 800 square meters. D, plot on a terrace about 2 meters higher than B. The plot comprises an area of 1,400 meters. E, plot on a level bench at 250 meters altitude. It comprises an area of about 800 square meters. F, plot on a gentle slope at the top of a ridge at 190 meters altitude. It comprises an area of 750 square meters.

TABLE XV.

Name.	A.	B.	C.	D.	E.	F.	G.
1. Aphananthe philippinensis	--------	5	27	27	--------	--------	59
2. Anisoptera vidaliana	9	8	13	6	8	4	48
3. Lagerstrœmia speciosa	--------	7	13	19	--------	--------	39
4. Canarium villosum	--------	3	9	14	--------	--------	26
5. Memecylon edule	--------	4	7	11	1	1	24
6. Dipterocarpus vernicifluus	1	5	--------	4	2	7	19
7. Artocarpus communis	--------	3	3	9	--------	1	16
8. Koordersiodendron pinnatum	3	4	3	1	3	1	15
9. Shorea polysperma	--------	--------	--------	--------	10	5	15
10. Shorea contorta	--------	--------	--------	--------	10	4	14
11. Grewia stylocarpa	3	--------	--------	--------	4	6	13

TABLE XV—Continued.

Name.	A.	B.	C.	D.	E.	F.	G.
12. Buchanania florida			2	8		1	11
13. Champereia cumingiana	1		3	7			11
14. Baccaurea tetrandra	2				5	3	10
15. Calophyllum wallichianum	1				5	2	8
16. Knema heterophylla	8						8
17. Semecarpus perrottetii		1	2	4		1	8
18. Strombosia philippinensis	6					2	8
19. Diospyros pilosanthera					2	5	7
20. Gnetum gnenom						7	7
21. Streblus asper		1	3	3			7
22. Adinandra pavonina		1		5			6
23. Chisocheton philippinum	5					1	6
24. Mallotus philippinensis				6			6
25. Parkia roxburghii	1	2	1	1		1	6
26. Santiria nitida	2				3	1	6
27. Shorea guiso	1			3	1	1	6
28. Ficus hauili		1	3	1			5
29. Pithecolobium acle	1	1	1	1		1	5
30. Pterocymbium tinctorium	4			1			5
31. Talauma villariana	1	1			2	1	5
32. Aporosa symplocosifolia		1			2	1	4
33. Cryptocarya luzoniensis	1				2	1	4
34. Palaquium tenuipetiolatum					2	2	4
35. Terminalia edulis		2		2			4
36. Aglaia turczaninowii				3			3
37. Canarium ahernianum					2	1	3
38. Dracontomelum cumingianum	1				2		3
39. Endiandra coriacea	1				2		3
40. Erythrina indica		3					3
41. Eugenia luzonensis		3					3
42. Euphoria cinerea		1			1	1	3
43. Garcinia venulosa		1	1	1			3
44. Grewia tiliæfolia				3			3
45. Hopea acuminata						3	3
46. Myristica philippensis					2	1	3
47. Palaquium oleiferum				2		1	3
48. Parinarium griffithianum		1				2	3
49. Symplocos polyandra		1			2		3
50. Turpinia pomifera	2					1	3
51. Xanthophyllum sp	2					1	3
52. Aglaia denticulata	1					1	2
53. Artocarpus lanceolata						2	2
54. Canangium odoratum		2					2
55. Carallia integerrima	1				1		2
56. Casearia fuliginosa				2			2
57. Cinnamomun mercadoi						2	2
58. Cyclostemon bordenii	1					1	2
59. Macaranga bicolor		2					2
60. Mangifera altissima			1	1			2
61. Mitrephora lanotan	1					1	2
62. Linociera cumingiana				2			2
63. Pittosporum pentandrum				2			2
64. Planchonia spectabilis		1			1		2
65. Unona clusiflora	1			1			2
66. Pterospermun obliquum			1			1	2

TABLE XV—Continued.

Name.	A.	B.	C.	D.	E.	F.	G.
67. Wrightia laniti			1	1			2
68. Zizyphus trinervis			1	1			2
69. Zizyphus zonulatus				2			2
70. Aglaia harmsiana			1				1
71. Allæanthus luzonicus	1						1
72. Antidesma leptocladum						1	1
73. Dysoxylum cumingianum	1						1
74. Arytera littoralis		1					1
75. Celtis philippinensis						1	1
76. Cyclostemon monospermus	1						1
77. Cyathocalyx globosus		1					1
78. Cyclostemon microphyllum						1	1
79. Garcinia binucao				1			1
80. Ellipanthus luzoniensis	1						1
81. Endospernum peltatum	1						1
82. Eugenia bordenii						1	1
83. Ficus nota						1	1
84. Flacourtia inermis	1						1
85. Glochidion sp				1			1
86. Gonocaryum tarlacense						1	1
87. Harpullia arborea			1				1
88. Laportea luzonensis		1					1
89. Litsea perrottetii		1					1
90. Homalanthus populneus				1			1
91. Macaranga mappa		1					1
92. Memecylon preslianum					1		1
93. Palaquium luzoniense			1				1
94. Premna nauseosa				1			1
95. Premna cumingiana		1					1
96. Quercus sp.						1	1
97. Reinwardtiodendron merrillii	1						1
98. Sterculia oblongata	1						1
99. Tarrietia sylvatica		1					1
Total							559

In the above plots, A, B, C, and D are on the border of the *Anisoptera-Strombosia* and the *Bambusa-Parkia* formation; consequently the vegetation partakes of the nature of both. The ones on the low river terraces show a strikingly different floristic and ecological composition from those on the slopes and more closely resemble the river terrace plot at an altitude of 100 meters. (See Table XIII.) Such species as *Aphananthe philippinensis, Lagerstrœmia speciosa, Canarium villosum,* and *Memecylon edule* are very suggestive of *Bambusa-Parkia* formation, and indeed these areas might be classed with the latter were it not for the absence of the bamboo. It is not at all unlikely that the physical factors more nearly resemble the *Bambusa-Parkia* than the *Anisoptera-Strombosia* formation. Only a careful measurement would determine this.

On the other hand, Plots E and F are nearer the *Dipterocarpus-Shorea* formation and consequently have some resemblance to it, both floristically and ecologically, as is shown by the occurrence of such species as *Shorea polysperma, Shorea contorta, Calophyllum wallichianum,* and *Hopea acuminata* (compare Plots E and F, Table XV, with Table XVI). *Anisoptera vidaliana* is fairly well distributed throughout all the plots, and for this reason the formation shares its name with *Strombosia.*

Lianas.—The liana vegetation of the plot on the river terrace at 100 meters altitude has already been discussed. Apparently its development here is much greater than it is in the closed forests, but in reality the difference is not very pronounced, though there is no doubt that the lianas occupy proportionately more space in the open than in the closed forests. (Pl. XIV.) Though the shade of the forest practically prohibits most lianas from obtaining a start from seed, yet they, as has been previously shown (p. 408), are not entirely dependent on seeds for the invasion of new territory. Especially is this true of the climbing bamboo and of at least one species of *Calamus,* though dicotyledinous lianas may also have this power. Even though the lianas did not possess this property, natural and artificial "blanks" occur in the forests and these would give opportunity for lianas together with other species to obtain a foothold from seeding.

Rattans.—Contrasted with the undergrowth of temperate regions, the species of the genus *Calamus* are most foreign. In their younger stages these climbing palms consist of a ground rosette of large leaves having their leaflets pinnate or arranged in groups, and, either above or below or on both the upper and under side, containing scattered, thin, flexible spines on the principal veins. In many cases the rachis of the leaf is prolonged into a long, whip-like runner (flagellum) having stout recurved hooks, the latter often arranged in groups; the leaf sheath is also strongly armed and may itself be provided with a long flagellum which in turn is armed. In time, from the center of the basal rosette, there arises a long scandent stem, the rattan of commerce, which may reach to the tops of the tallest trees or it may scramble over the ground, sometimes reaching a total length of 120 meters or more. After these stems are well developed, the basal rosette disappears. Among the species common at Lamao are *Calamus mollis major* (Uay), *C. ornatus philippinensis* (Limoran), and the undetermined species having the native names of *Ditan, Palasan, Culacling, Babuyan,* and *Bucton.* (Pl. XV.) Of these, *Bucton* has a distinct, though short, trunk so that the basal rosette stands at least 20 centimeters above the ground. *Limoran* has the habit of producing runners and of thus starting new centers at some distance from the mother plant. These, in turn, may throw out runners which enable the plant to spread without going through the dangerous seedling stages. Without exception, all the species are able to endure the most intense shade, although they, like other lianas, present a much better display of foliage, at least nearer the ground, when they grow in half open places. (See Pl. XVI.) They also share with the climbing bamboo and other forms, the habit of creeping into "blanks" in the forest and they thus retard what would otherwise be the rapid entrance of tree species into such places. Usually, the rattan growth is scattered through the forest (see Pl. XV), but often individuals are so densely set (Pl. XVI) that it is difficult to pass through such a location because of the armed flagella which, curving downward, catch the clothing. By occupying space and by increasing the already dense shade, they often prevent the germination and development of valuable tree species. With the exception of *Uay,* all the species of *Calamus* here are mesophytic.

Other lianas.—Other families represented by lianas are the *Pandanaceæ* and the *Araceæ.* Characteristic of the former is the genus *Freycinetia* with the species, *F. luzonensis* and *F. ensifolia. F. luzonensis* climbs to the tops of largest trees, the ends of its shoots bend stiffly outward and upward and develop closely crowded leaves which give a characteristic "pandan" tone to the vegetation. Often species of *Araceæ* of the genus *Pothoidium* and *Rhaphidophora* begin their growth semi-epiphytically near the bases of large trees and afterwards climb by means of roots; at the same time, positively geotropic roots reach to the soil and insure a more constant supply of water to the older plant.

Dicotyledinous forms present on the river plain are also encountered in the forest. Besides the ones already mentioned, *Artabotrys cumingianus, Agelæa wallichii, Strongylodon macrobotrys, Entada scandens, Modecca sp., Uvaria sp.,* and others (see Pl. XIV) may also be present.

Transition from epiphytes to lianas.—The transition from the epiphyte to the liana is best expressed by the genus *Ficus* of the section *Urostigma.* (See Pl. XVII.) The species of this group begin as epiphytes on the rough surface of the bark or on other parts of the tree where the seeds can find lodgment; here they germinate, the roots eventually reaching and penetrating the ground. In time there is developed a lattice-like growth which envelopes the host, and then, as the parts increase in diameter, the plant assumes a tree-like habit which enables it to exist independently of its host, which eventually dies. The natives term the species of *Ficus* which have developed this habit "balete," which, to some extent, species of *Schefflera* of the *Araliaceæ* simulate. Plate XVIII shows a seedling of *S. venulosa* which has developed on soil which collected in a knot hole of *Pithecolobium acle.* Plates XVII, XVIII, XIX, and XX depict species of *Ficus* in several stages of maturity. Often from branches of the plant there are developed one or more large roots which eventually reach the ground. From the base to the top of the mountain species of "balete" are found scattered throughout the forest.

Epiphytes.—The epiphytic vegetation in contrast with that of the higher altitudes is but poorly developed. Mention has been made already of the orchids of the river terrace. The rough limbs of *Terminalia edulis,* which grow in more or less protected places, seem to be a favored position for many individuals of *Cymbidium aloifolium, Aerides quinquevulnera,* and *Rhynchostylis violacea;* on the higher and more xerophytic parts of the tree there were many specimens of the fern *Drynaria quercifolia.* The branches of *Lagerstrœmia speciosa, Ficus caulocarpa,* and other trees afford a good surface for the germination of orchid seeds; the semiparasitic *Hoya multiflora* is also not infrequently encountered. Several species of orchids, and the ferns *Drynaria, Vittaria lineata,* were noted on the branches of the tall *Dipterocarpaceæ.* Species of *Loranthaceæ,* although present, are less common than they are in the parang.

Herbaceous vegetation.—One of the surprises of the forest is the scarcity of herbaceous plants growing in the dense shade during both the dry and wet seasons. Even in the open places there are found only a few geophilous *Araceæ,* some grasses, small species of *Acanthaceæ* as *Gymnostachyum affine, Hypoestis subcapitatus, Lepidagathus hyalina,* and others. Scattered throughout the forest is the sedge *Hypolytrum compactum.* This species, with a few ferns and *Begonia rhombicarpa* on the more damp slopes, are the only truly herbaceous plants which were noted in the dense forest.

Plank buttresses.—Schimper[37] has called attention to the prevalence in tropical countries of trees with plank buttresses or board roots. He claims that these are a peculiarity in a tropical climate where the rainfall is abundant and that they are found in the evergreen-rain, and in most of the deciduous, monsoon forests.

Prevalence of buttresses.—In the *Anisoptera-Strombosia* formation out of 39 fairly mature trees 15, or 38 per cent, had no buttresses, 13, or 33 per cent, had buttresses over 0.5 meter, and 11, or 29 per cent, less than 0.5 meter in height. The buttresses assume various shapes. Some extend up the trees to a height of 3 meters or more and are less than a meter in width; others are as broad as they are long; still others, usually low ones, branch. Of those observed, species of *Anacardaceæ* (*Dracontomelum cumingianum* and *D. mangiferum*) exhibit the best-developed ones, the buttresses of one specimen of *D. cumingianum* being 3½ meters in height by 3 in width. As a rule, young trees show but little or none of this development. Old trees of *Dipterocarpus vernicifluus* may or may not have them. One of these showed a buttress which was narrow but at least 7 meters in height; another equally large tree had none. *Eugenia glaucicalyx* has three equally strong buttresses which are developed in such a way as to divide the circumference of the trunk into three nearly equal parts. (See Pls. X, XI, XII, XXI, XXII, XXIII.)

Cause of buttresses.—The buttresses seem to be correlated with broadly developed crowns (Pl. XII). *Dracontomelum cumingianum,* for instance, a tree usually growing in open places, has long, scraggy branches with coarse twigs on the ends of which are rosettes of large, compound leaves. In the forest where the crowns are dominant, and where they have an opportunity to develop horizontally as well as vertically, the buttresses are correspondingly large. This horizontal growth is especially marked in the *Bambusia-Parkia* formation, where the dicotyledinous trees overtop the bamboo. Here *Parkia* itself shows strong buttresses. In the formation higher up the mountain the buttress habit is present, but not so prevalent; it disappears altogether on the exposed ridges of the mountain.

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[37] **Loc. cit., 304, 305.**

It will be seen that the same causes which operate to produce short, thick boles in open places in temperate regions are possibly also present here, with the difference that the buttresses, which take the place and perform the function of the uniformly thick trunks, appear later in the life of the tree. This means that the tree in youth, while it is crowded in the forest, develops a regular bole, but that when it reaches above the surrounding vegetation, in response to the increasing heaviness of the top, the buttresses appear at the base, enabling the tree to withstand the extra strain. It is possible that this of itself is the stimulus causing the development. It is known that the presence of heavy limbs often produces extra growth in the trunk at a point just beneath the insertion of the branches, and the fluted appearance so commonly observed in such cases is the result. The cause for this growth is ascribed to the stimulus due to the extra strain, although why such a stimulus should produce this result is not known. A transference of the strain to the base of the trunk would likewise cause prolific growth at the point or points where its influence is felt the strongest; this point would be at the attachment of the roots, and especially of the larger ones, and thus would cause the development of board roots or plank buttresses. So long as the tree top is protected on all sides by others, the strain will not be very great for two reasons, i. e., the top will not have a chance to broaden out and it will not be exposed to strong winds, but so soon as it emerges above the tops of other trees, the exposure and the increasing heaviness above will produce a strain sufficiently great to cause a stimulus of growth at the base and thus produce the buttresses. However, whatever may be the cause, there is no doubt that the abundance and size of buttresses in many instances is associated with the *dominance* of certain trees over others, and thus the irregular profile of the forest results. This is strongly emphasized by the fact that in places where the trees reach a more uniform diameter and height and where they are set sufficiently close to produce a class with an *intermediate* crown, or, to express it in another way, to form a regular profile, the buttress habit is not so pronounced. Such is the case in places in the *Anisoptera-Strombosia* formation and it is more prevalent in the *Dipterocarpus-Shorea* one which is to be discussed below.

Trunks.—The shape of the bole of the tree is of the greatest importance to the forester. Other things being equal, the more nearly the bole reaches a true cylinder throughout its entire length, the more lumber will it produce. In other words, the more nearly the *form factor* reaches *one* the higher the value of the log. It has been shown that for some species of trees the board roots are not developed so long as the trees do not become *dominant.* If it be desired to suppress the buttress habit for such species, it will be found effective to adopt a sylvicultural treatment which will keep species of the same *crown class* together, so that throughout the entire rotation none will become dominant. In some parts of the Lamao Reserve such a system is already naturally realized. On the other hand, it may be expedient as fully as possible to develop the board roots, for certain timbers are valuable for broad table tops. In such cases a sylvicultural system, the reverse of the one just given, would produce the desired results. If the strain is the cause of the development of plank buttresses, then this could be concentrated by the removal of the less desirable ones, so that the others would receive more of it and thus become stimulated to better development.

Fluted trunks.—In some trees at the top and at the base of the bole there is a tendency to develop a fluted appearance. In such individuals, especially if the trunk is short, the grooves are apt to be more or less continuous throughout the entire length, although the middle portion is more nearly circular in cross section. *Euphoria cinerea, Eugenia luzonensis* (Pl. VI), *Dracontomelum cumingianum, Reinwardtiodendron merrillii, Turpinia pomifera,* species of *Ficus,* and others may have such irregular trunks. Many trees do not have the buttress habit in any situation. Among those which may sometimes become dominant are species of *Anonaceæ,* as *Cyathocalyx globosus* and *Canangium odoratum,* and in other families *Bombax ceiba, Zizyphus zonulatus,* and of those which seldom reach above the second-story vegetation, *Strombosia philippinensis, Antidesma edule,* and many others may be mentioned.

Tree habit.—In the *Anisoptera-Strombosia* formation, aside from *Bambusa, Gnetum gnemon,* and *Pandanus luzonensis,* there are only a few scattered individuals of plants that have acquired the tree habit in the great groups of *Pteridophytes, Gymnosperms,* and *Monocotyledons. Gnetum gnemon,* as shown by Tables XIII and XIV, forms a conspicuous element in the second-story vegetation of the forests. It rarely reaches a height of more than 12 meters. It is easily distinguished by its very broad, opposite mesophytic leaves and the joints of the trunk. These latter cause the bole to resemble a bamboo with short, thick internodes. (See Pl. XIV.) The liliaceous *Dracæna angustifolia,* represented only by a few trees over 4 meters tall, is nevertheless conspicuous by many specimens under this height and by its long, narrow, clasping leaves. Only one specimen of a tree fern, *Alsophila contaminans,* is present (see Pl. XXVI). This will be discussed in another connection. Near the upper limits of the *Bambusa-Anisoptera* formation there are two groves of the palm *Orania palindan,* and a few scattered specimens were noted elsewhere. One grove of eight trees of *Cycas circinalis* was found in a semi-open place within this formation.

Shape of crown.—Aside from the regular oval or irregular tree crowns, a number of types worthy of mention were noted. *Polysias nodosa,* which in the parang usually has a single rosette of large compound leaves, in the closed forest reaches tree dimensions of considerable size and has from three to six short branches at the top, each of which ends in a rosette of leaves. Many *Meliaceæ* have similar crowns; in young trees there is a single rosette, and in older ones there are rosettes on the ends of secondary and tertiary branches. This, as already shown, is the habit of *Dracontomelum cumingianum. Koordersiodendron pinnatum* has a similar habit. *Orania palindan, Cycas circinalis,* and a tree fern, *Alsophila contaminans,* are among the smaller trees which have a single rosette of compound leaves. Of those which have a single rosette of large simple leaves are *Semecarpus gigantifolia, Macaranga mappa,* and *Ficus psudopalma.* By far a majority of trees have an oval or spherical crown or a more or less irregular one. Aside from compound leaves of members of the *Leguminosæ,* the *Meliaceæ, Burseraceæ,* and *Anacardiaceæ,* most of the trees have simple, entire leaves. Those with a serrate or wavy margin are the exception. Guttered leaves are represented, though sometimes obscurely so, by species in the *Moraceæ* (*Ficus*), *Guttiferæ* (*Calophyllum* and *Garcinea*), *Myrtaceæ* (*Eugenia*), and others.

Bark of trees.—Nearly all writers on tropical vegetation have called attention to the thin bark of tropical trees as compared with those growing in temperate climates. This is due to the weak development of the corky tissue. The measurement of the bark of 44 mature or nearly mature trees, representing different species, shows an average thickness of 6.87 millimeters. Of those measured, *Palaquium luzoniense,* with a bark 15 millimeters in thickness, represents the maximum, and *Antidesma edule,* with a bark 2 millimeters thick, the minimum. The cause of the weak development of the corky tissue is generally attributed to the effect of humidity on the formation of bark. Where the humidity differs, observations have not been extensive enough to show any appreciable variation between the development of bark on the same species in the trees of the Lamao Reserve, found in two or more plant formations. (See Pls. X, XI, XIX, XXI, XXII, XXIII, XXIV, and XXV, for bark characters.)

Notes collected in reference to the bark of nearly a hundred different species show that in a majority of cases this is smooth, and light gray or brown in color. In many instances the surface is more or less thickly set with *corky pustules* of various shapes and sizes. In the case of the rhamnaceous *Zizyphus zonulatus,* short, thick pyramidal thorns are characteristic. In *Diospyros pilosanthera* the pustules are more or less thornlike, but do not assume any regular shape. In many trees with more or less smooth bark, it is shed at irregular intervals in large or small scroll-like patterns. In the myrtaceous *Tristania decorticata,* as the specific name implies, the whole bark is shed periodically. In this respect it resembles the closely related *Eucalypti.* In other genera of *Myrtaceæ* the bark becomes papery. In *Eugenia luzonensis* the corky layer, which is a light red, peals off in this papery fold very much like the birch. In *Eugenia bordenii* the thin layers are light gray instead of red. While gray or brown are the predominating colors of barks, yet there are exceptions. In *Diospyros pilosanthera* and other species it is nearly black. A yellow bark distinguishes *Calophyllum wallichianium* at once. In many cases the bark is ridged. Usually the ridges are low and correspondingly the depressions are shallow. Of course, in many species the rough barks do not appear until the tree has attained some degree of maturity. Among these trees which have rough barks may be mentioned *Palaquium luzoniense, Anisoptera vidaliana* (in very old age), *Shorea contorta, Koordersiodendron pinnatum,* and others. In *Pithecolobium acle* and in *Bischofia trifoliata* the corky layer consists of choppy flakes turning outward at the free, lower edge.

Sap of bark.—Aside from the outer, the middle and inner barks often have distinctive characteristics which enables one to place them in the family. In the case of the *Anonaceæ* the strongly marked, medullary rays of the inner bark form alternating bands parallel with the radii of the trunk. The exudation of sap from the cut bark also is often striking, and with or without other characteristics will enable one to identify the families. Thus, in the *Myristicaceæ* represented by *Myristica* and *Knema,* the bark when cut freely exudes a red sap. In the genera *Calophyllum* and *Garcinia* of the *Guttiferæ* the sap is yellow. In the *Dipterocarpaceæ* a nearly colorless resin is slowly exuded. In the *Burseraceæ,* in species of *Canarium* and in *Santiria nitida,* a similar resin is found which burns readily. The white and often abundant milky sap of the trees in members of the *Moraceæ, Apocynaceæ,* and *Sapotaceæ* will distinguish these families from others, though often other characters are necessary to tell them one from the other.

It will be seen from the above that frequently there are family, generic, or specific differences substantial enough to warrant the collecting of data for a key which will enable one to distinguish the many species by bark characteristics. Undoubtedly, the need of such a key for the practical forester is great, for the difficulty of obtaining flowers or even leaves from the tall trees, coupled with the multiplicity of species, makes the task of mere determination a difficult one.

Cauliflory.—Schimper[38] associated cauliflory with thin bark characters. Other authors associate it with conditions of pollination. Buscalioni[39] claims that the cauliflower habit is a primitive one and persists in plants of hot, moist regions. The ecological advantages are numerous. In many cases heavy fruits are produced which, if not attached to a strong, woody stem, would be easily broken off. Such is the case in many *Meliaceæ,* where the fruits often become large, and, when grouped on one stem, very heavy. *Ficus minahassæ* (see Pl. XXVI) has a fruit stalk which often is 3 meters in length and thickly covered with fruit. No small twig could possibly support such a weight. An enumeration of the plants of the Lamao Reserve which possess cauliflory would include species in many of the large families. However, instances where the trunk bears the flowers or fruit are not common. Among those observed were *Eugenia whitfordii, Ixora macrophylla,* and a number of species of *Ficus.* An undetermined species of the anonaceous *Goniothalamus* had the short flower-stalk springing from a root at the base of tree. Very numerous are the trees which exhibit an attachment of the flowers to the smaller and larger branches. Another significance ascribed to cauliflory is protection of both the flower and the fruit from too much heat and rain.

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[38] L. c. 336.

[39] Buscalioni, L., *Sulla cauliforia. Malpighia* (1904) **18:** 116–176. A full bibliography of the subject is given with this paper.

Clearings in forest.—Clearings made in the midst of the *Anisoptera-Strombosia* formation often by Negritos, usually fill up rapidly with climbing bamboo and are similar in character to those described under the *Dinochloa* parang. However, no extensive tracts have ever been cleared. In Plate X is shown a river terrace from which the second-story growth has been taken. Plate XXVII is a view of a portion of this same terrace about two years later. The forest was opened sufficiently so that light-loving species could thrive. Many weeds (see p. 395) had gained a foothold and other species enumerated in connection with the plate have invaded this region from an open, rocky terrace, near by. That the clearing will quickly recover its normal condition is evidenced by the fact that species of the standing trees already have seedlings in the new growth.

Seedlings.—As most of the data for this paper were collected during the dry season, there has been little opportunity to study the early condition of the seedling process. The tables in which are given the actual number of young trees under 4 meters in height show some results. For instance, *Anisoptera vidaliana* in the open places on the rocky terrace (Table XIII) show many more young than old trees, while on the more closed adjoining hillside (Table XIV) there are fewer young than old ones. In *Parkia roxburghii* the difference is still more striking. The conclusion is that these two trees are exceedingly intolerant of shade. This is especially true of *Parkia.* After the rainy season sets in, many seedlings of *Anisoptera* were observed in rather shady forests, though they were always more plentiful in open places. On the other hand, *Dipterocarpus vernicifluus* shows a large number of young trees in the closed forests, and corresponding with a less number of larger trees in the open places, there are fewer seedlings. During the rainy season many seedlings of this tree were found in very dense shade. The large, winged seeds germinate lying on top of the ground. In open places, even well stocked with seeds, only a few seedlings were found. This indicates conclusively that the shaded conditions are the best for this species. Facts deduced from the table and from some observation during the rainy season show that *Koordersiodendron pinnatum* resembles *Anisoptera* in its seeding habits; that is, it will tolerate shade, but it does better in more open places. Correlated with the light-loving habit one finds the seed of *Koordersiodendron pinnatum* and *Parkia roxburghii* germinating to some extent before the rainy season sets in. On the other hand, *Anisoptera* did not, though many seeds were present. *K. pinnatum* has a fleshy fruit which is eaten by the wild hogs. The seeds, however, pass through the intestines of the animals undigested and are buried in loose ground made by the rooting of the hogs, where in a few days they germinate. Thus the seeds may not only be carried long distances by hogs, but are also planted by them. However, the young tender seedlings which germinate may be eaten by the same animal, so that the advantages which this tree would have over others is partially counteracted by the same agent. Many very young trees of *Calophyllum wallichianum* were observed both in open and closed places, though in the latter they are most numerous. On the other hand, many species represented by larger trees show no seedlings at all. *Lagerstrœmia speciosa* is a striking example of this. Though seeding abundantly during both seasons in which it was observed, not a single seedling could be found. Efforts to germinate these seeds in the nursery proved unavailing. Species of *Dipterocarpaceæ* other than those discussed show an average number of young trees present, but as these species did not fruit abundantly during the two seasons under consideration, the sylvicultural habits as regards light can not with certainty be determined. A reference to the tables will show the proportion of young to old trees in other species. Much work remains to be done on the seedling condition of the principal forest trees before any definite conclusions can be reached.

Topography and soil.—The topography of the *Anisoptera-Strombosia* formation consists of a series of ridges alternating with deep cañon-like valleys. The gradient of the slopes of the valleys is approximately 25 degrees, although, of course, it may be more or less. We have seen that corresponding to the surface diversity there are types of forests which differ in species and in leaf structure. Here, as in other formations where the slope is steepest, the surface wash is greater and consequently the soil is shallow. Usually, also, the exposure is great. All these combine to make a lower chresard and consequently a more xerophytic vegetation.

Especially are these conditions obtained on the ends of ridges which terminate abruptly at the junction of the branches with the main streams of the river. Attention has also been called to the character of the vegetation on the rocky flood plains of the river. Here, though the underground water level is rather near the surface yet, because of the nearly absent soil and the hydrodynamic effect of the flooded stream, the vegetation is inclined to be more or less unstable and consequently open.

Slightly higher terraces where the surface wash of the slopes adjoining them has been deposited, exhibit the best conditions for growth. However, such terraces are narrow. On the gentle slopes, with a gradient of 20° and under and on top of the level ridges, good vegetation conditions are obtained.

The soil, as already shown, is composed of a heavy clay, the residual of the andesitic rocks of the mountain. The depth, even on rather steep slopes, is surprisingly great. All through the formation, holes in many instances 2 meters deep made by Negritos in search of the wild yam occur. In some instances the residual soil on narrow level ridges is as much as 3 meters in depth and perhaps more. In many places, however, the disintegrated portion of the rock is at or near the surface; in such places the vegetation is thin. Here deciduous or evergreen trees with xerophytic structures are common.

An analysis [40] of soils collected on the tops of ridges and on terraces shows the following:

TABLE XVI.

	H_2O, 100°-105°.	Loss on ignition.	CaO.	P_2O_5.	N.	K_2O.	Na_2O.	Humus.	Water capacity.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
I	6.98	11.89	0.12	0.06	0.03	0.11	0.23	3.99	54.06
II	7.59	13.36	.26	.08	.12	.09	.20	2.77	56.71
III	6.99	8.45	1.05	.07	.15	.12	.98	2.28	51.92
IV	6.34	11.29	.22	.13	.13	.09	.51	3.29	51.30

Description of soils.—I is the surface soil of a ridge; II, collected at depth of 15 centimeters in the same situation; III and IV are surface soils collected from terraces.

Humus.—It will be seen that the soils are not deficient in essential elements and that the water-holding capacity is high. The absence of humus in the soil of tropical forests has long been a subject for discussion. Schimper,[41] quoting Wohltmann, claims that humus covers smaller areas in the Tropics than in temperate zones. In South India, however, about one-third the area is covered with a rich soil containing 8 to 9 per cent of organic matter. The analyses of the soils in question show an average humus content of 3.09 per cent, which in comparison with twenty soils [42] given by Stockbridge is rather high. Of the twenty which he mentions, the Lamao soils are surpassed by only three. Nevertheless, in comparison with the mass of half-decayed organic material of the beech or maple forests which is so prominent in some places in temperate regions, the Lamao soil is poor. The intermediate stage between the forest litter and the almost completely disintegrated organic matter is passed over quickly in the Tropics. This, perhaps, will account for the impression that the humus accumulation is not great. It must be remembered that the forces which bring about the decomposition of complex organic compounds, both of plants and animals, are much stronger in the Tropics, and because of the continuous warmth they are continually at work. Thus there is no accumulation of organic, decaying matter in the intermediate stages. In temperate regions, on the other hand, the accumulation during the whole year is greater than can be disposed of during the short, warm period in which nitrifying bacteria and other agents of decay would be operative; consequently, each year a surplus is added to the constantly increasing mass. In regions of great rainfall, where during heavy rainstorms the surface becomes a sheet of water, a great deal of organic litter is washed into the streams and thus lost to the forest. Especially is this the case in regions of rough topography, where the drainage is excellent.

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[40] All soil analyses given in this paper were made by L. A. Salinger of this Bureau. The methods for chemical analysis are those adopted by the Association of Official Agricultural Chemists. See Bull. 46 (revised edition), *U. S. Dept. of Ag. Div. of Chem.* Water capacity, loss on ignition, humus, and loss of water at 100°-105° are calculated on air-dry soil.

[41] L. c., 380.

[42] Stockbridge, H. E. Rocks and Soils, 250, 1895.

Correlated with the scarcity of half-decomposed organic matter is a rather scanty development of fleshy fungi, though at the beginning of the rainy season a number of forms appear. Woody fungi, however, are constantly in evidence, usually on old logs or standing dead trunks. Among the genera present may be mentioned *Auricularia, Schizophyllum, Sterum, Polystichus, Polyporus, Fomes,* and *Trametes.* Mosses and liverworts are scantily represented. Lichens are found abundantly on the smooth bark of the trees and on boulders. Other than the crustaceous forms are almost entirely absent.

Many of the ecological and structural characteristics of the *Anisoptera-Strombosia* formation are also present in the other formation, so that a repetition of this matter will not be necessary. However, where differences occur, attention will be called to them. It has been noted that in the *Bambusa-Parkia* formation many xerophytic and tropophytic structures appear. In the *Anisoptera-Strombosia* formation the same condition is obtained, but to a less extent. The evergreen element is much more pronounced and the deciduous nature correspondingly less characteristic. This is in accord with the more mesophytic conditions which prevail here in contrast with the lower formation. However, as shown by the tables, many plants prevail in both habitats. Trees like *Parkia, Lagerstrœmia,* and *Ficus* with a partial deciduous habit are present, though less conspicuous in the *Anisoptera-Strombosia* than in the *Bambusa-Parkia* formation.

Summary.—1. In the *Anisoptera-Strombosia* formation a two-story vegetation prevails; the bamboo story of the *Bambusa-Parkia* forest is replaced by small dicotyledinous trees represented by *Strombosia.*

2. The forest conditions and consequently *forests* are less xerophytic and tropophytic during the dry season; though the deciduous habit is present, no trees are deciduous throughout the entire dry season. This brings the forest more nearly in accord with Schimper's tropical rainy forest than the *Bambusa-Parkia* formation.

3. The two-story vegetation gives prominence to certain dominant species, among which members of the *Dipterocarpaceæ* predominate both in number and actual volume.

4. The development of plank-buttresses is often associated with the dominant trees.

5. The great floristic complexity of the forest is in striking contrast with that of temperate forests.

6. Within the formation, various physiographic situations support different types of vegetation. The mesophytic slopes and narrow terraces support the climax vegetation, the rocky, flooded terraces are unstable, and the exposed ridges a more or less xerophytic vegetation.

[TO BE CONTINUED.]

ILLUSTRATIONS.

PLATE I. View looking southward from Buenavista Peak to Cabcaben Peak along the rim of the crater, which is on the right. The tree with an umbrella-shaped top seen on Cabcaben Peak, the ridge leading to it, and on the rim of the crater is *Leptospermum amboinense.* The rock in the foreground is in Plot H, Table XXIII. *Freycinetia* sp., a liana, is in front of it. Behind the rock on the right is *Eugenia congesta,* on the left are *Photina luzonensis* and one specimen of *Vernonia arborea.*

II. Looking across the cañon near the head of the Lamao River to Caybubu Peak and the ridge leading to it. Caybubu Peak is shown on the left. The steep slopes of the cañon are densely wooded except where almost perpendicular sides have made conditions too unstable for tree vegetation.

III. View of parang vegetation. The large tree is *Parkia roxburghii* covered with a species of *Loranthus. Parkia* is in the process of forming new leaves. Note the jungle-like thicket beneath. *Bambusa-Parkia* formation.

IV. View in the "parang." In the center is *Artocarpus communis.* Below it on left, the small tree with a rosette of large leaves is *Ficus pseudopalma. Ficus hauili, Leea manillensis, Tabernæmontana pandacaqui,* and *Gmelina hystrix* are also present. Note the abundance of liana species. *Bambusa-Parkia* formation.

V. View on the edge of a clearing. On the left is *Areca catechu;* on the right a coppice growth of *Artocarpus communis.* In the background a dense growth of the exotic species *Prosopis juliflora,* which is common near the coast. *Bambusa-Parkia* formation.

VI. View in an easily flooded, dry river channel. On the right and left are specimens of *Eugenia luzonensis;* in the center is a large specimen of *Pandanus luzonensis.* Beneath is dense growth of the marantaceous *Donax arundastrum.* The flood plain here is sandy. *Anisoptera-Strombosa* formation.

VII. View on river terrace about 3 meters above low water. In the center is a specimen of *Pandanus whitfordii;* on the left of it is *Garcinia venulosa* with *Dinochloa diffusa* over it. In the foreground is a species of rattan (*Calamus*) ; the large tree in the background is *Anisoptera vidaliana. Anisoptera-Strombosia* formation.

VIII. View of a low, rocky terrace easily flooded. Along the edge of the stream at the right is *Homonoia riparia,* a willow-like euphorbiaceous shrub; next it, in the center of the photograph, are *Pandanus luzonensis* and the grass *Saccharum spontaneum.* The trees in the background, beginning from right to left, are *Dysoxylom schizichitode, Anisoptera vidaliana,* and *Sarcocephalus cordatus.* Photograph taken near close of the dry season. During the wet season this terrace is frequently flooded. *Anisoptera-Strombosia* formation.

IX. View on a river terrace 5 meters above low water. This terrace is never flooded. Trees present on left of the trail are *Dipterocarpus vernicifluus, Grewia stylocarpa, Cyathocalyx globosus;* on the right *Cyathocalyx, Ellipanthus luzoniensis, Shorea concorta, Dipterocarpus vernicifluus.* Note the abundance of bamboo, rattans, shrubby undergrowth and lianas. *Anisoptera-Strombosia* formation.

X. A terrace similar to that shown in Plate IX, with the undergrowth removed. Note the density of the forest, prevalence of low buttress roots, and the dead hanging lianas. *Anisoptera-Strombosia* formation.

XI. View on a terrace similar to that shown in Plate X. Note the prevalence of trees with fairly regular trunks. *Anisoptera-Strombosia* formation.

XII. Another view of a river terrace where the forest has an uneven profile. Note the large dominant *Dipterocarpus vernicifluus* with a tall buttress root. *Anisoptera-Strombosia* formation.

XIII. View across a banana field, showing in the background the irregular profile of a part of the *Anisoptera-Strombosia* formation.

XIV. View on a slope with a gradient of about 15 degrees. Passing from left to right are the following trees: *Anisoptera vidaliana* (with crooked trunk), the anonaceous *Xylopia dehiscens, Shorea polysperma* (large tree near the center), *Gnetum gnenom* (well in the background), and *Xanthophyllum* sp. Note the prevalence of lianas (principally *Agelœa wallichii*), rattans, and fairly good reproduction. *Anisoptera-Strombosia* formation.

XV. Vegetation on a slope of 35 degrees. Note the absence of many large trees and presence of rattans. Trees are *Strombosia philippinensis, Gnetum gnenom, Aporosa symplocosifolia, Cyclostemon bordenii,* etc. *Anisoptera-Strombosia* formation.

XVI. Vegetation in an open place where a species of *Calamus* (limoran) forms a dense growth. *Shorea-Plectronia* formation.

XVII. A species of *Ficus* or "balete" inclosing the trunk of *Crypteronia cumingii.* Note the large root on the right. *Shorea-Plectronia* formation.

XVIII. Shows the character of the bark of *Pithecolobium acle;* also a young plant of *Schefflera venulosa* starting in the soil accumulated in a knot hole. This latter species has the "balete" habit. *Anisoptera-Strombosia* formation.

XIX. A species of *Ficus* enveloping a tree of *Bischofia trifoliata. Shorea-Plectronia* formation.

XX. Shows the characteristic, net-like growth of a species of *Ficus* on *Santiria nitida. Anisoptera-Strombosia* formation.

XXI. View in the interior of a forest of the *Shorea-Plectronia* formation. Note the large buttresses of *Eugenia glaucicalyx.* Large tree on the right in the background is *Shorea polysperma.* Other trees shown are *Plectronia viridis* (several specimens on the right), *Cinnamomum mercadoi, Palaqium tenuipetiolatum, Thea montana, Memecylon edule,* and *Ternstrœmia toquian.* Note the scarcity of undergrowth and forest litter, and the presence of crustaceous lichens on the trunks of the trees. Photograph taken in Plot A, Table XIX.

XXII. View in the interior of a portion of the *Shorea-Plectronia* formation on a slope of 25 degrees. On the left is a large tree of *Eugenia glaucicalyx;* to the right of it is *Shorea polysperma;* between them in the background is *Calophyllum whitfordii.* (For other trees in this plot see Plot B, Table XIX.) The herbaceous vegetation is represented by *Carex continua.*

XXIII. Shows the bark characters and many low buttress roots of *Quercus bennettii.* Other trees present: *Shorea polysperma, Thea montana, Symplocos oblongifolia,* and others. *Shorea-Plectronia* formation.

XXIV. View into interior of a portion of the *Dipterocarpus-Shorea* formation. The three large trees are *Dipterocarpus grandiflorus, Gonocaryum tarlacense* is in front of the one on the left. Note the absence of buttress roots and the presence of a deep litter of leaves. Rattans are also present.

XXV. Base of the trunk of *Agathis philippinensis,* showing character of the bark and the exudation of the resin known as almaciga. (Gum copal.) *Shorea-Plectronia* formation.

XXVI. Eroding bank of the Lamao River. In the background is the tree fern, *Alsophila contaminans.* On the left is *Macaranga bicolor* and below it is *Ficus minahassæ.* On the right is a large tree of *F. minahassæ,* showing the hanging flower stalks originated on the trunk or the base of the larger branches. At the base of the tree fern are *Begonia rhombicarpa,* the fern *Polybotrya appendiculata,* and species of *Selaginella. Anisoptera-Strombosia* formation.

XXVII. Portion of terrace shown in Plate X, taken sixteen months later. All the undergrowth present started from seed. Note the presence of the large-leaved *Macaranga mappa;* also *Macaranga bicolor* and *Homalanthus populneus,* all these species being characteristic of recent clearings. *Anisoptera-Strombosia* formation.

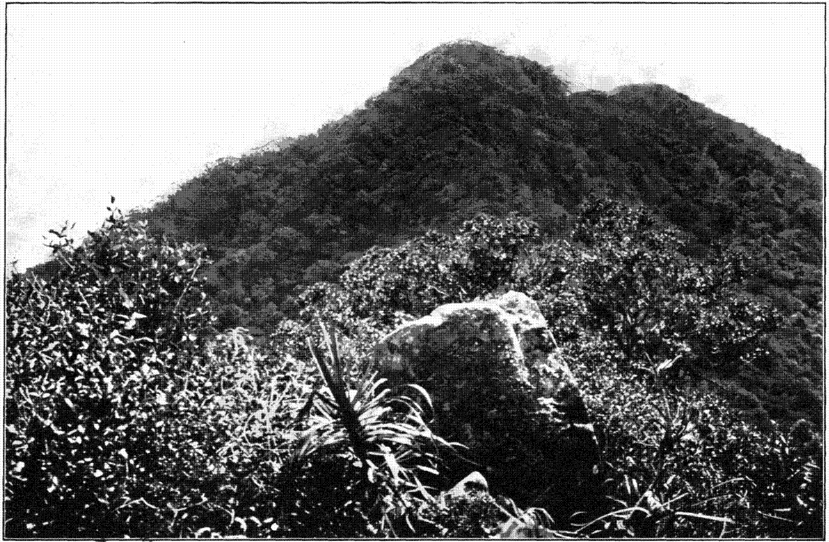


PLATE I.

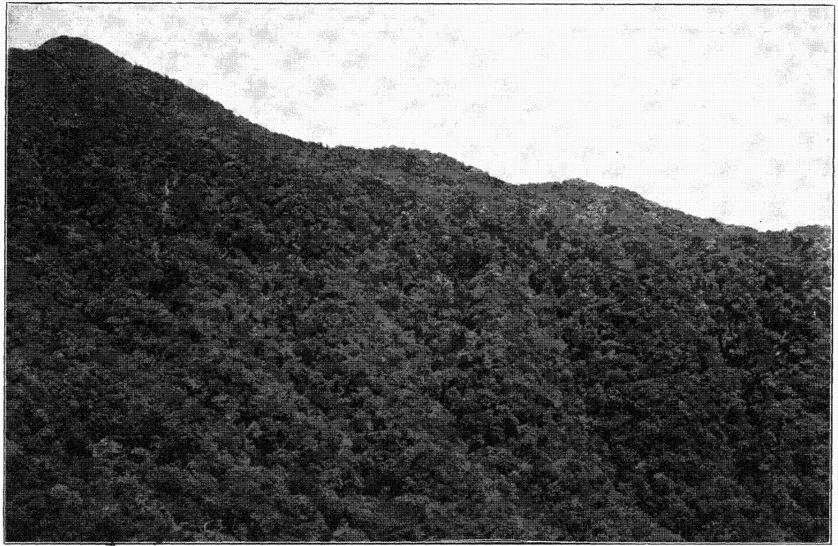
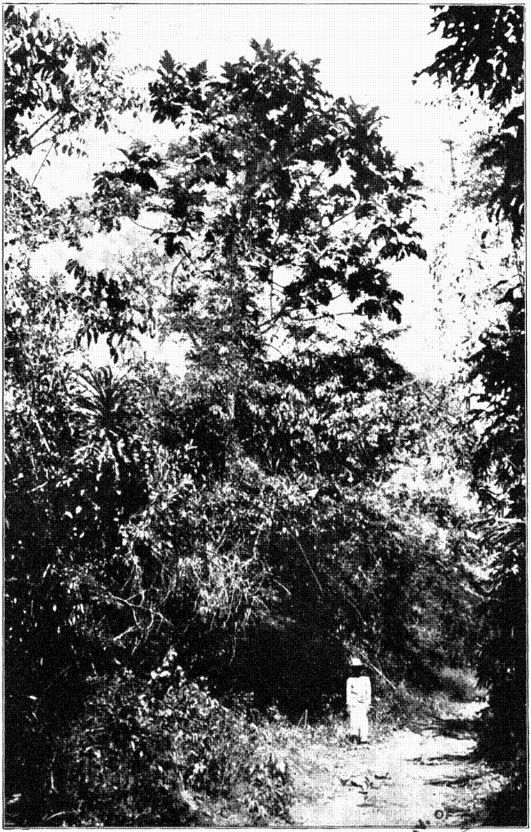


PLATE II.

PLATE III.



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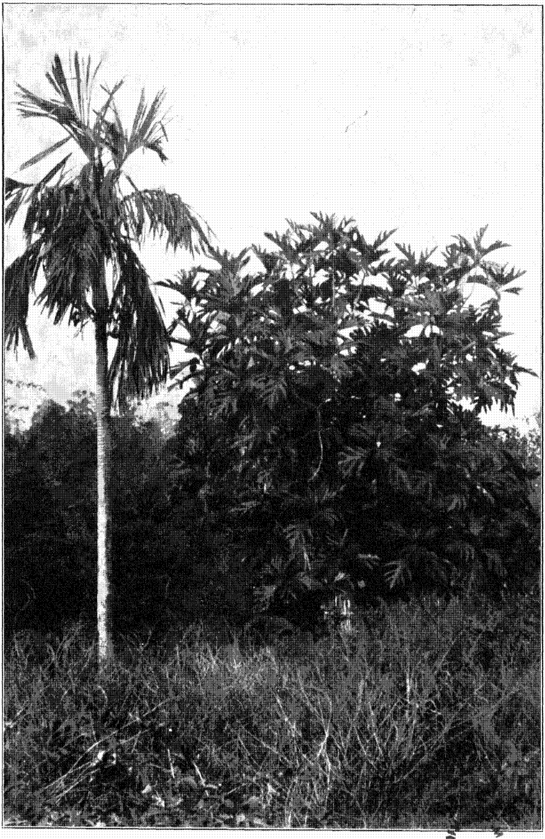

PLATE V.

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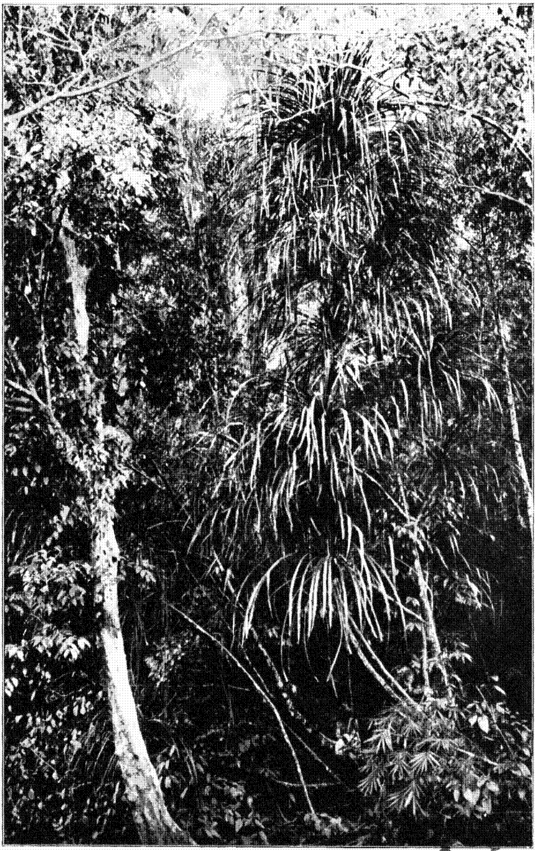


PLATE VI.

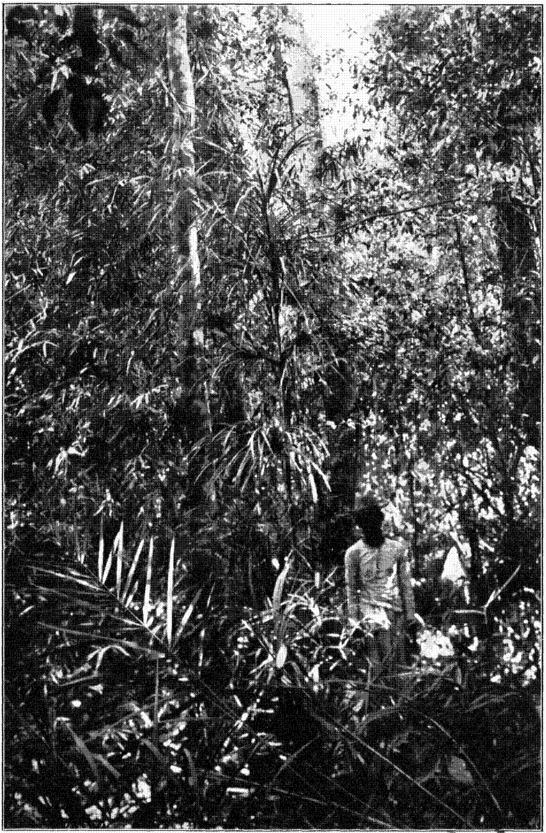


PLATE VII.

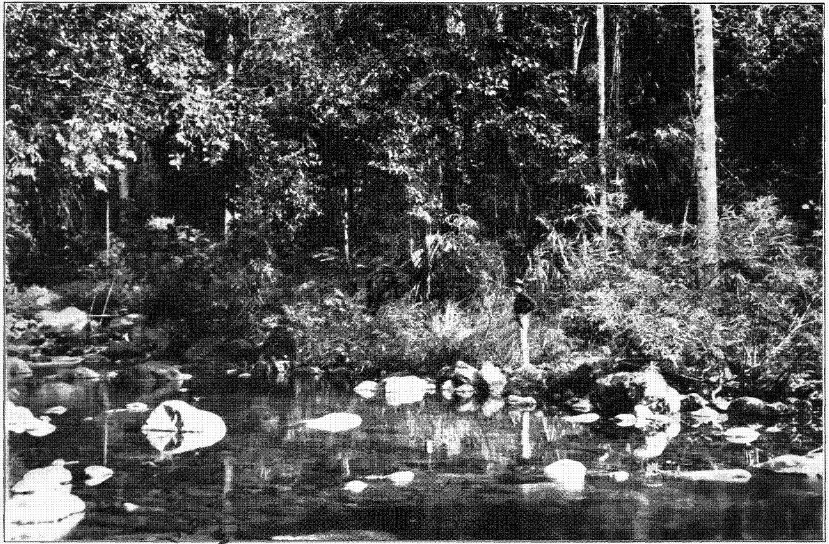


PLATE VIII.

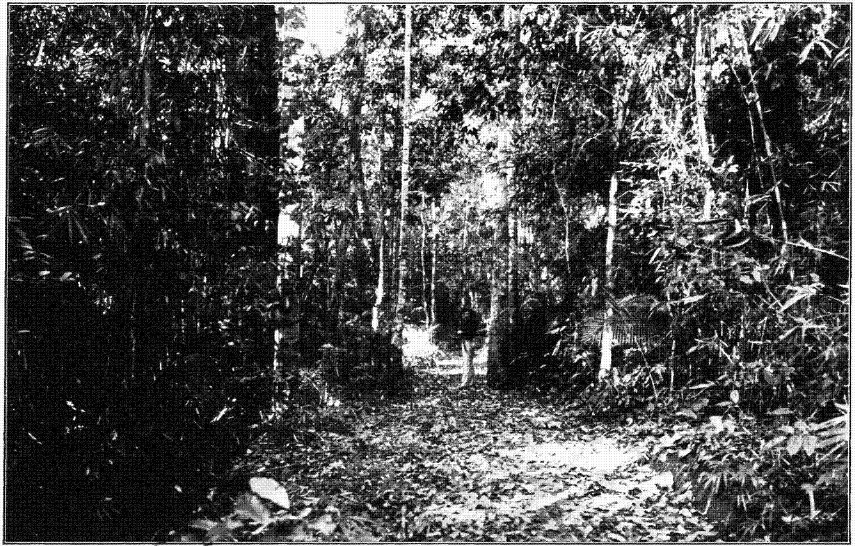


PLATE IX.

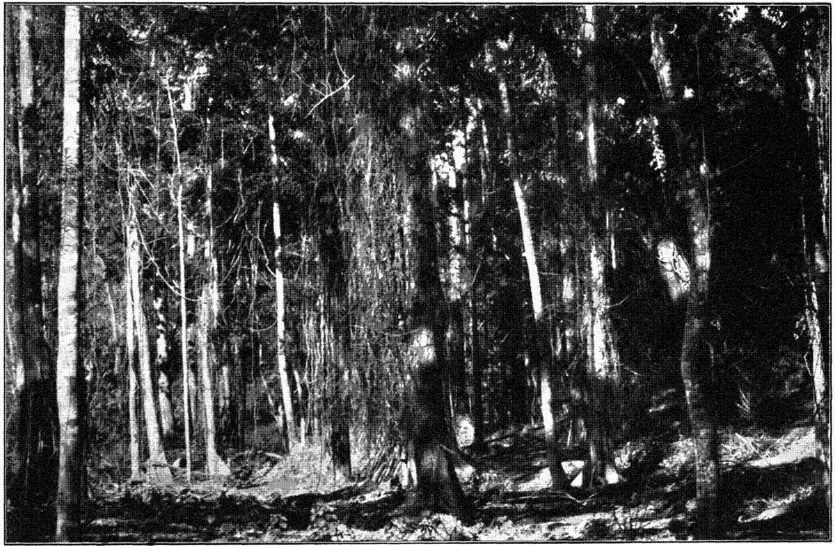


PLATE X.

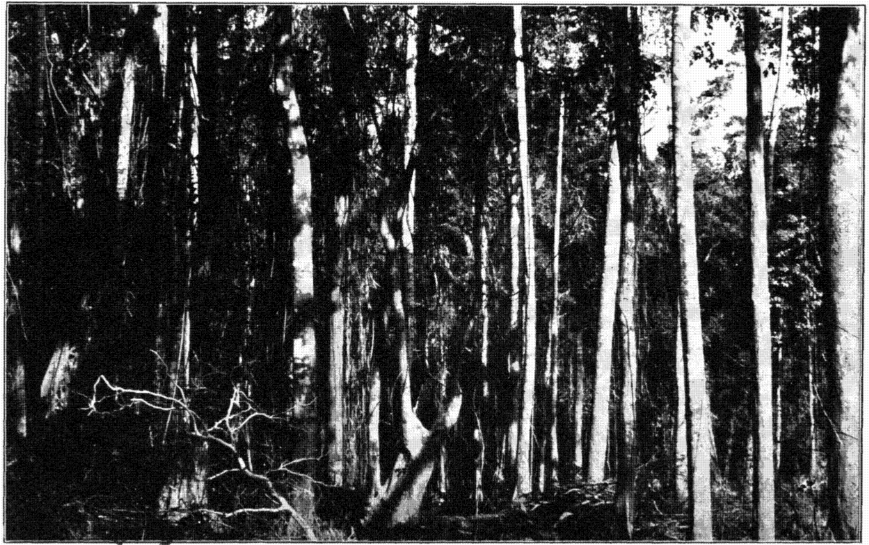


PLATE XI.

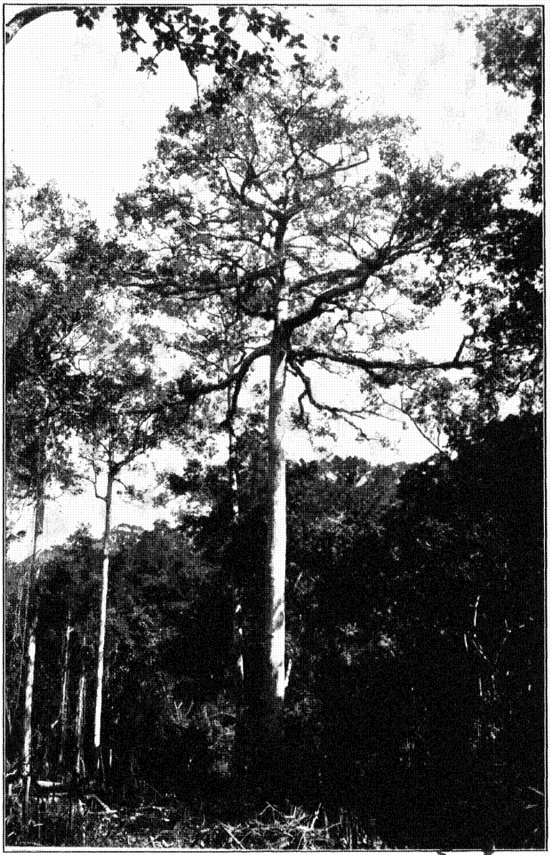
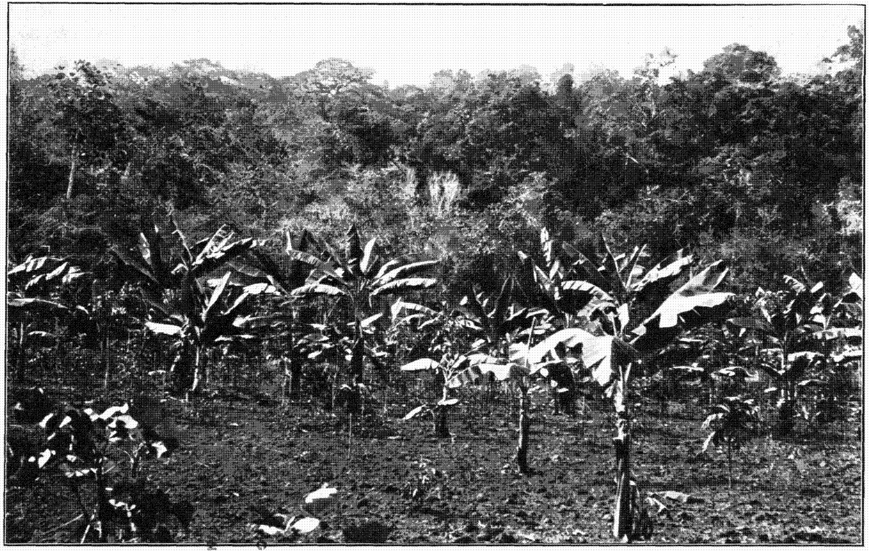


PLATE XII.



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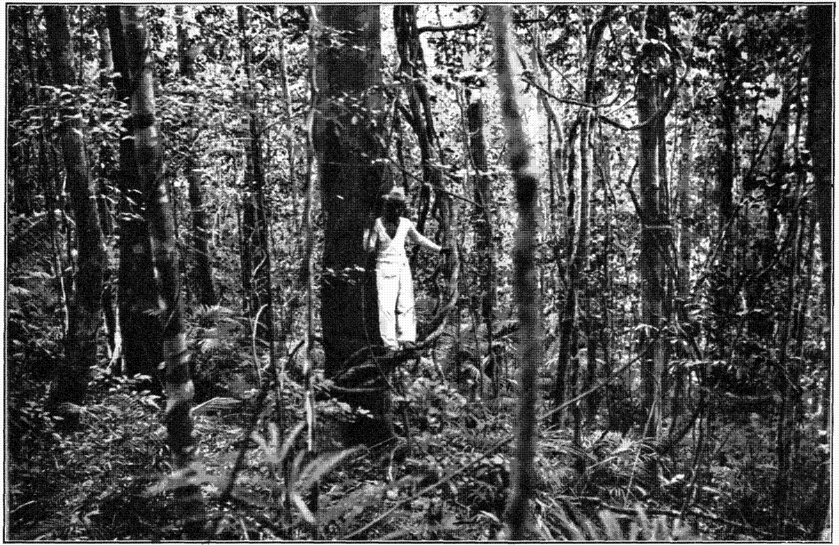
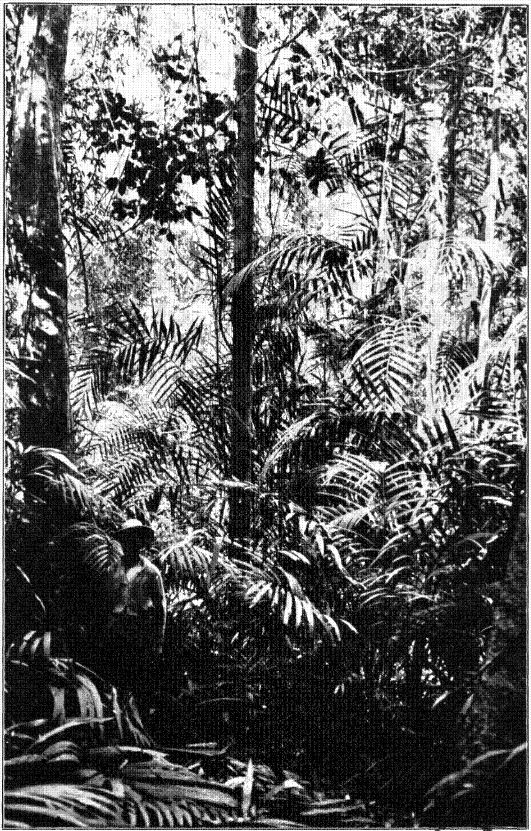


PLATE XIV.

PLATE XV.



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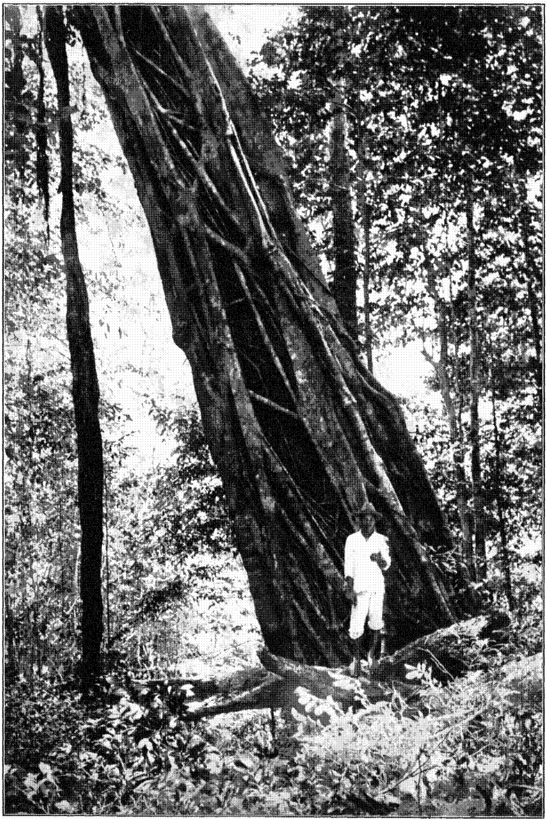

PLATE XVII.

PLATE XVIII.

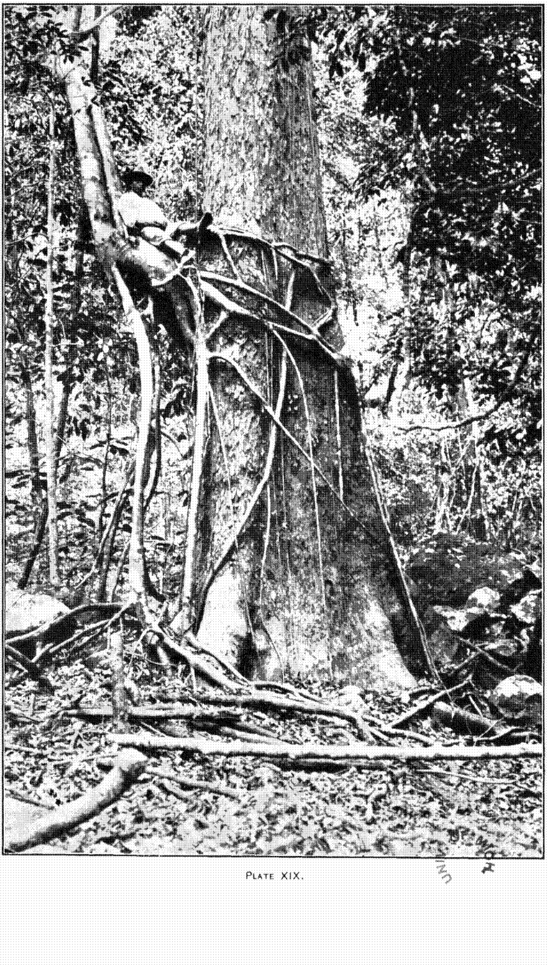

PLATE XIX.

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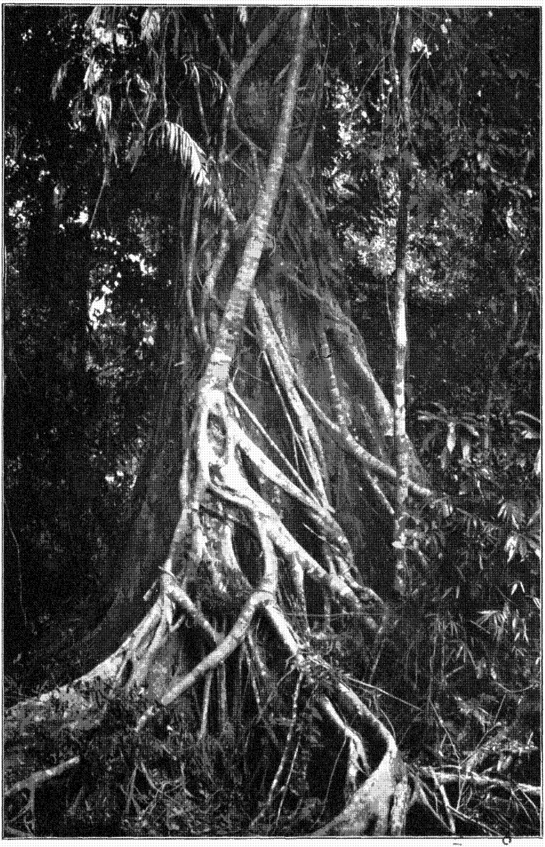

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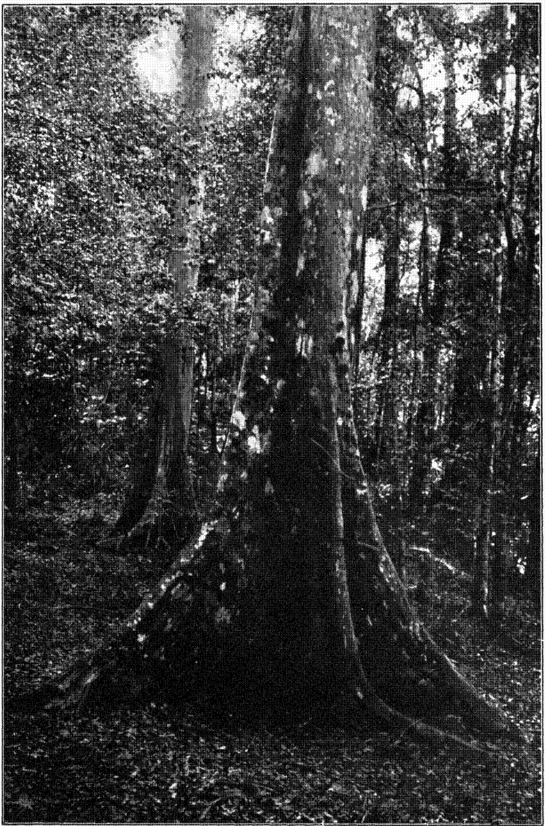

PLATE XXI.

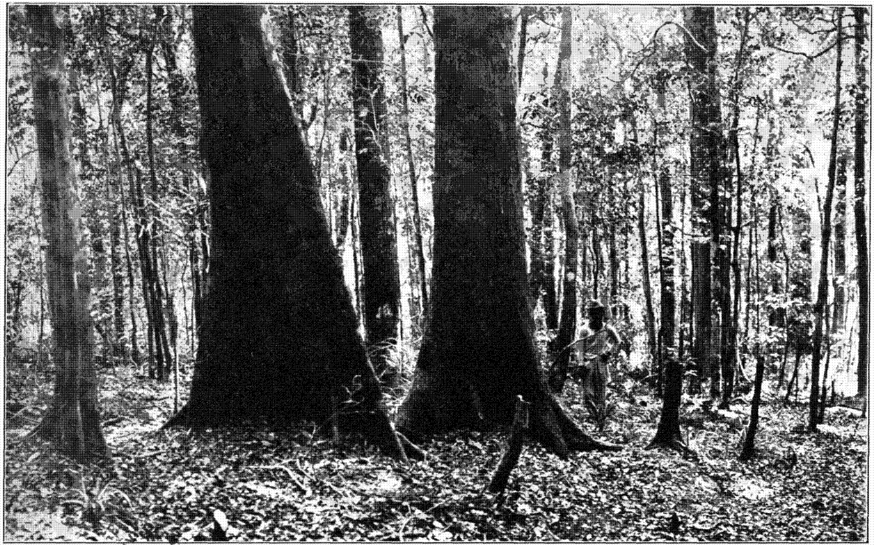

PLATE XXII.

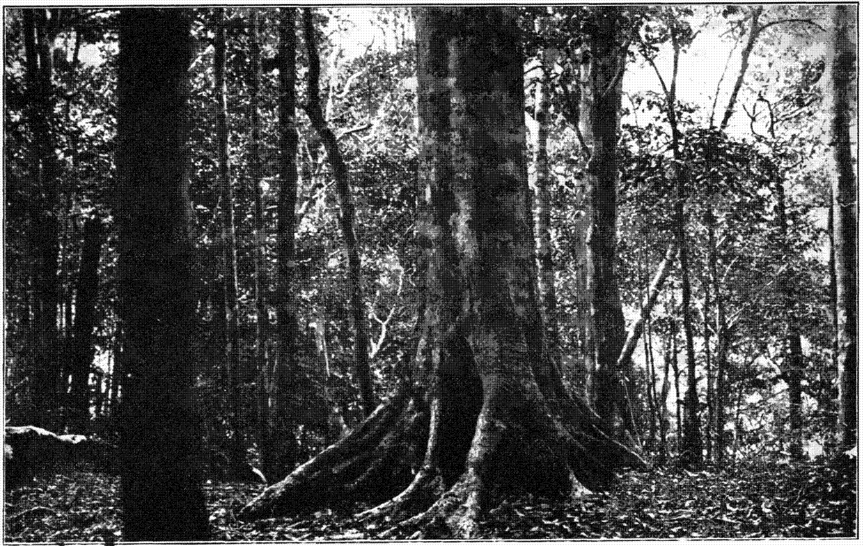

PLATE XXIII.

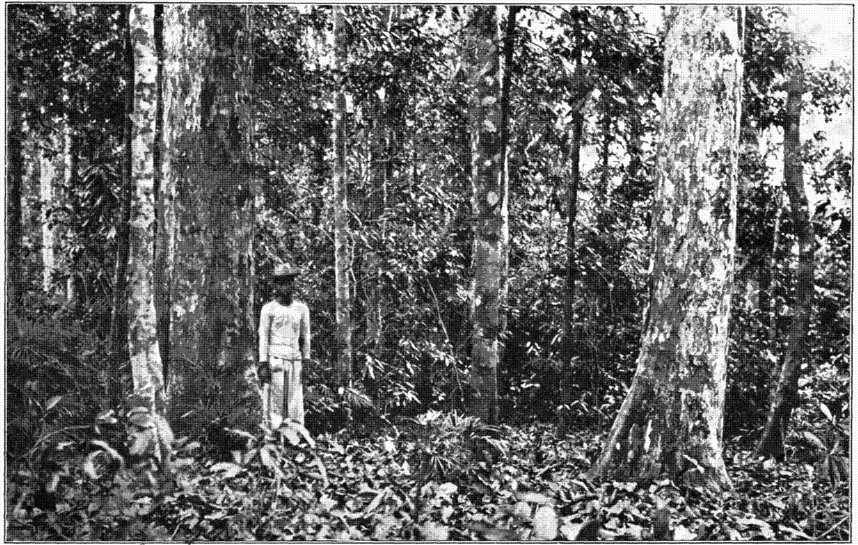

PLATE XXIV.

PLATE XXV.

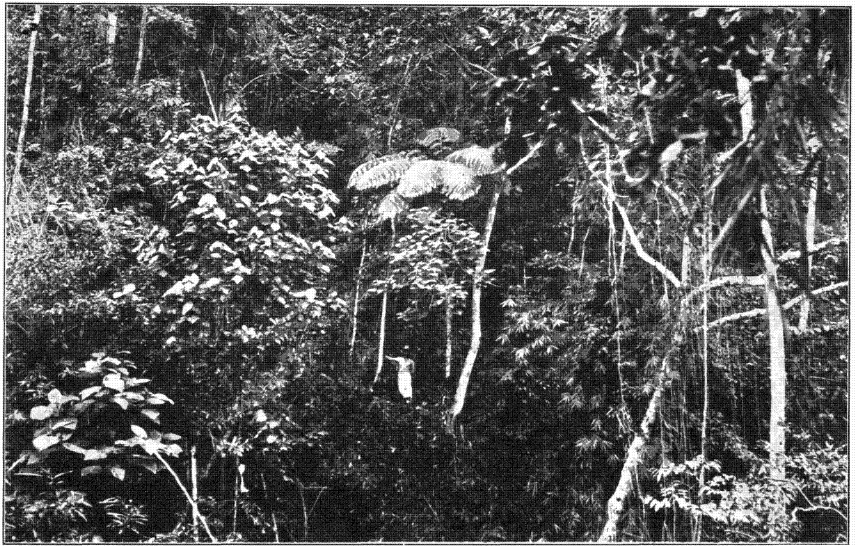

PLATE XXVI.

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PLATE XXVII.

COLOR IMAGE PLACEHOLDER

OVERSIZED PLACEHOLDER

TEST-PSYCHO

THE WATERS OF THE CRATER LAKES OF TAAL VOLCANO WITH A NOTE ON SOME PHENOMENA OF RADIO-ACTIVITY.

By R. F. Bacon.
(*From the Chemical Division, Bureau of Science.*)

The crater of Taal Volcano, in the Province of Batangas, central Luzon, has in it two very remarkable pools. They are known as the Green Lake and the Yellow Lake, respectively, owing to the color of their waters. About 2 liters of water was obtained from each of these by the members of an expedition from this laboratory, who visited the volcano during the present dry season (January, 1906).

The volcano consists of a series of elevations containing, among others, a large crater about 3 miles long and 2 miles wide, rising from the waters of Lake Taal. Within this is a small crater, at present active in the solfotaric stage, and the ash cones of several dormant ones. There are also three lakes within the boundaries of the large extinct crater; two of these have been mentioned above, the other is in the crater of the present active cone and it was not accessible at the time of this expedition. The water of this lake is at a boiling temperature and large volumes of steam continually rise from its surface; the temperature of the other two, at the time of the visit, was only a little above that of the air (about 38° C.). These lakes are described as being boiling hot by former investigators and there is little doubt but that they may change very markedly from season to season.

These waters were considered to be deserving of investigation because, as they possibly had such free access to the depths of the earth, they might be of an extraordinary composition. The analyses proved that, while the concentration and acidity of the waters were remarkably high, rare or unusual elements could not be detected in the amount of liquid available, neither were we able to demonstrate that the samples were radio-active, but this lack of radio-activity may be due to the fact that they had been standing for about four weeks before it was possible to make the necessary tests. A rock sample obtained from the yellow pool was not radio-active. The determinations were made by dissolving a portion of this sample in acid and then drawing air through the solution and into a gold-leaf electroscope, the construction of which is described below. This specimen was a very porous basalt which had soaked up a large quantity of water, and on standing in the laboratory it gradually became covered with a growth of alum crystals which were colored yellow by a small amount of ferric salt. In appearance the crystals deceptively resembled those of sulphur, and there is no doubt but that many statements concerning the large amount of sulphur in volcanic craters would be more accurate if iron salts were taken into consideration. The negative results obtained from this rock make it appear probable that there are no radio-active salts in solution in the water.

Water No. 1 was of a decidedly green color and when brought into the laboratory was comparatively free from sediment; No. 2 was of a greenish-yellow and was partially filled with a sediment which largely consisted of gypsum. No odor of hydrogen sulphide or of sulphur dioxide was perceptible in either water and microscopic examination revealed no organized matter.

Qualitative analysis showed the presence of ferrous and ferric iron, ammonium, aluminum, phosphoric acid, magnesium, calcium, potassium, sulphuric and chlor-ions, barium and strontium (spectroscopic determination only). No cæsium or rubidium could be detected.

The quantitative analysis is as follows:

Quantitative analyses of waters from the crater of Taal Volcano.

[Figures express grams per 100 cc. of the water.]

	No. 1.	No. 2.
Color	Green.	Yellow.
Sp. gr. at 15° C.	1.1062	1.1763
Acidity	1.28 N.	2.08 N.
Acidity calc. as H_2SO_4	6.14%	10.28%
Calc. as HCl	4.65%	7.57%
Total solids (filtered water), by heating to 110° for 6 hrs.	15.8678	25.7235
Total solids (unfiltered water), by same method	15.9312	30.3175
(Sediment difference)	.0634	4.5940
SO_4	4.1303	5.6768
Cl	6.3143	11.2760
Fe (total)	1.031	1.711
$\ddot{\text{F}}\text{e}$	.7150	1.3250
$\dddot{\text{F}}\text{e}$	.3160	.386
Al	1.1892	3.485
Na	1.7217	.9343
PO_4	.0273	.0391
Ca	.0934	.1042
Mg	.9432	1.8210
K	.0418	.0514

The following is the analysis made by José Centeno[1] in 1885, calculated as ions, the results expressed in grams in 100 cc. water. No. 1 is described as the yellow or more northerly lake and No. 2 as the green one.

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[1] José Centeno, "*Estudio Geológico del Volcán de Taal*" 21, 22. Also in Becker "*Reports on Geology of the Philippine Islands*", p. 49. Extracts from *21st Annual Report U. S. Geol. Survey* (1899–1900), Part III.

	No. 1.	No. 2.
Total solids	2.6988	6.0022
$\overset{..}{Fe}$	.1315	.3036
$\overset{...}{Fe}$	.0209	.0612
Na	.6471	1.2405
K	.0372	.1821
Cl	1.2873	3.4596
SO_4	.4122	.4186
PO_4	.0396	.0515
Al	.0143	------
Mg	.0264	.0335
Ca	.0150	.0136
Free acid calc. as H_2SO_4	.15%	
Free acid calc. as HCl		.894
SiO_2	.0640	.074

A comparison of these two analyses with the recent ones from this laboratory shows a marked difference; the water we obtained is much more concentrated and the content of free acid is higher.

In connection with the study of the radio-activity of these waters, some very curious phenomena were noted, of which it is desired to make a preliminary announcement at this time. The general arrangement of the apparatus we used was that of H. Mache.[2] In place of the large bell-jar containing the electroscope, a Novy anaërobic jar was used. In this was constructed an electroscope similar to that described by Boltwood.[3] Behind the gold leaf was placed a photographed scale which was magnified by a suitable arrangement. In ordinary, diffuse light in the middle hours of the day, the rate of discharge of the electroscope was very constant, the gold leaf moving one division of the scale in five minutes. However, it was noted that late in the afternoon the rate became much slower, being one division in ten to fifteen minutes. In the sunlight it was found that the discharge rate was very markedly increased, averaging 18 divisions in five minutes. Experiments in total darkness gave a total discharge rate of 1 division in two hours. These experiments in each case extended over a period of from thirty minutes to four hours and the rate was then calculated to a unit time of five minutes; however, readings were generally made every five minutes, and for given conditions the rate was usually quite uniform throughout a series. We have also noted a singular behavior in uranium salts placed in the sunlight. The air passed through an aqueous solution of a uranium salt after the latter had been exposed to sunlight for a short time is about twice as active in discharging the electroscope as it is from the same solution kept in diffused light, this acquired activity being rapidly lost

[2] *Monatshefte für Chemie* (1905), **26**, 595.

[3] *Am. Jour. of Sci.* (Sill.) (1904), **18**, 97.

on removing the salt from sunlight. This result is not surprising in view of the work of Seekamp[4] and others in which they demonstrated the powerful catalytic action which uranium salts displayed only while in the sunlight.

The general action of sunlight is often such as to make chemical substances better conductors of electricity.[5] Thus, in the sun's rays, sulphur, phosphorus, selenium,[6] and mercuric sulphide[7] are changed into modifications which more easily conduct the electric current. Silver[8] and gold[9] oxides lose and lead oxide[10] and manganous oxide[11] gain oxygen, each to give a substance which offers less resistance to the passage of the current. In aqueous solution the same facts are noted. Chlorine and bromine water give the respective halhydric acids; an aqueous solution of sulphur dioxide,[12] even in the absence of free oxygen, is changed in the sunlight into sulphuric acid and sulphur; a solution of potassium iodide gives the better conducting potassium hydroxide;[13] ferric chloride with oxalic acid and with alcohol[14] gives a mixture with increased conductivity, and the same is true of mercuric chloride in conjunction with ammonium oxalate.[15]

Hertz[16] showed that a spark is formed much more easily in air when the spark gap is in the light than when it is in the dark, and Arrhenius[17] from his own work and that of Hertz on the conductivity of gases at low pressure under the influence of light makes the deduction that light has a tendency to ionize the air and thus to make it a better conductor. Mrs. Ayrton[18] among many curious experiments demonstrated that a candle flame could discharge an electroscope very rapidly at a distance of 40 centimeters. Many more instances can easily be added to this list. We believe there is here a more general relation which has not as yet been explained and therefore we expect to study these interesting phenomena in a much more exhaustive manner. For this purpose we have ordéred apparatus of sufficient delicacy, but at the time of writing the proper instruments are not available in the Philippines, and for this reason we beg to reserve the field for a short time. We expect in our next communication to be able to report more authoritatively on the radio-activity of the Taal waters, including those of the lake inside the present active cone, and an expedition will probably be organized to obtain samples before the eruptions attendant upon the rainy season may possibly have destroyed the lake. We believe such observations will be of value in judging certain theories of the present day concerning the radio-activity of the surface of the earth. For the sake of completeness an analysis of the water of the larger lake surrounding the volcano, which was made some two years ago by Mr. F. A. Thanisch, formerly of this Bureau, is appended.

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[4] *Ann. d. Chemie* (Liebig) (1862), **122**, 113; (1865), **133**, 253.

[5] See J. Gibson, *Ztsch. Phys. Chem.* (1897) **23**, 349. Arrhenius, *Wien Akad.* (1887) **96**, 831.

[6] *Proc. Roy. Soc.* (1889) **46**, 136.

[7] Heumann, *Ber. d. chem. Gesell.* (1874) 7, 750. Böttger, *Chem. Centralbl.* (1875) 291.

[8] Arrhenius, *Wien. Akad.* (1887) **96**, 831.

[9] Chevreul, C. R. (1858) **47**, 1007.

[10] Schonbein, *Edmann's Journal* (1850) **51**, 273.

[11] Chastaing, *Ann. Chim. Phys.* (1876) (5) **11**, 145.

[12] Idem, *l. c.*

[13] Pogg. *Ann.* (1863) **119**, 497.

[14] Chastaing, *l. c.*

[15] *Wien Akad.* (1880) **80** (2) 636.

[16] Hertz, *Wied. Ann.* (1887) **31**, 983.

[17] Arrhenius, *Wied. Ann.* (1888) **33**, 643.

[18] *Nature* (1902) **65**, 390.

[Results expressed as parts in 100 cc.]

Total residue	0.1716
Fixed residue	0.1484
Loss on ignition	0.0232
Free NH_3	Trace.
Nitrites	Traces.
Fe_2O_3 Al_2O_3	0.00042
Ca	0.005339
Mg	0.004942
Na	0.045634
SiO_2	0.00315
Cl	0.0720
SO_4	0.01913
CO_2, as bicarbonate,	Considerable.

The water has a slightly alkaline reaction and contains a slight white deposit.

The above demonstrates the radical difference between the waters of the lakes within the crater and of that of the lake surrounding Taal Mountain.

CONCERNING SILVER OXIDE AND SILVER SUBOXIDE.

By GILBERT N. LEWIS.
(*From the Chemical Division, Bureau of Science.*)

On account of the uncertainty as to the correctness of the value at present accepted for the electrolytic potential of oxygen, I have attempted to calculate this extremely important quantity by an indirect method. One very necessary datum needed in this calculation is the decomposition pressure of silver oxide at 25°. The determination of this pressure is the subject of the present paper. Incidentally it will be necessary to consider the suboxide of silver which, by certain chemists, has been supposed to exist.

LeChatelier[1] was the first to show the reversibility of the reaction,

$$2\ Ag_2O = 4\ Ag + O_2.$$

By the decomposition of silver oxide in a closed tube at 300° he obtained a pressure of 10 atmospheres. On the other hand, by heating silver at the same temperature in oxygen at 15 atmospheres he observed the oxidation of the silver. He therefore placed the decomposition pressure of silver oxide between 10 and 15 atmospheres.

Knowing this pressure for one temperature, and the heat of decomposition, it should be possible to calculate with the aid of the van't Hoff equation, the pressure at another temperature. However, such a calculation must be made with great caution. In the first place, we must be sure that at both temperatures we are dealing with precisely the same reaction.

Guntz[2] has undertaken to show that the pressure he obtained by heating silver oxide at 358° was not the decomposition pressure of silver oxide but of silver suboxide. In other words, he believed that silver oxide at first decomposed entirely into suboxide and oxygen, according to the equation,

$$4\ Ag_2O = 2\ Ag_4O + O_2,$$

and that the suboxide then partially decomposed until equilibrium was reached, according to the equation,

$$2\ Ag_4O = 8\ Ag + O_2.$$

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[1] *Zeit. Phys. Chem.* (1887), 1, 516.

[2] *C. R.* 128 (1899), 996.

The existence of such a suboxide would not prevent the determination of the equilibrium pressure in the system, Ag, Ag_2O, O_2 for this pressure could readily be calculated from the equilibrium pressure in the system Ag_2O, Ag_4O, O_2, and that in the system Ag_4O, Ag, O_2. However, I shall show that in experiments covering a wide range of temperature, the suboxide never appeared and that the experiments which led M. Guntz to believe in its existence are probably to be interpreted otherwise.

I shall first describe measurements of the decomposition pressures at several temperatures and then show that the quantities thus obtained represent true equilibrium in the system Ag_2O, Ag, O_2.

Two samples of silver oxide were used. These will be referred to as A and B. A was prepared from hot, dilute barium hydroxide and silver nitrate as described in my paper on the kinetics of the silver oxide decomposition, carbon dioxide being excluded.[3] B was the preparation of Merck, labeled "highest purity." Both samples before being used were heated for several hours at 300°.

DECOMPOSITION PRESSURE AT 325°.

The first experiment was made at 325° [4] in the thermostat of molten sodium and potassium nitrates which I have described in the paper just mentioned. The apparatus for measuring the pressure consisted of a stout, brass tube, about 2 meters long and 1 centimeter in internal diameter, closed at the lower end and at the upper connected with a metallic manometer. In the lower end of the brass tube was fitted a thin, glass tube 7 cm. high containing the silver oxide (Sample B). In order as far as possible to diminish the total air space in the apparatus, the rest of the brass tube was filled as nearly as possible with a close fitting glass rod. After the apparatus had been exhausted through a stopcock provided for this purpose the lower end of the tube was introduced into the thermostat to a depth of about 30 cm.

The decomposition began in a few hours and in five days the pressure reached a constant maximum as shown in Table I.

TABLE I.

Time in hours.	Pressure in atmospheres.
12	18.5
24	26.5
48	29.8
72	30.1
96	31.5
120	31.8
144	31.8

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[3] *Zeit. Phys. Chem.* (1905), **52**, 310; *Bulletin of the Bureau of Government Laboratories, Manila,* No. 30.

[4] All thermometers used were compared with Reichsanstalt standards. The corrected temperatures are given.

In order to approach the equilibrium from the other side the tube was then heated for a few hours at a higher temperature and returned to the thermostat. The pressure at first registered 34.0 atmospheres and then fell gradually as shown in Table II.

TABLE II.

Time in hours.	Pressure in atmospheres.
0	34.0
24	33.4
48	32.5
72	32.3

According to these data the true pressure of equilibrium lies between 31.8 and 32.3. The manometer had been verified by comparison with a standard manometer but may have been in error by a considerable fraction of an atmosphere. Therefore, we will take in round numbers 32 atmospheres as the decomposition pressure at 325.°

During this whole experiment there was not the slightest leakage from the tube and the whole apparatus was eminently satisfactory. Unfortunately, the work was interrupted at this point by my removal from the chemical laboratory of Harvard College to the Government Laboratory of the Philippine Islands and the experiments had to be continued with other apparatus.

THE DECOMPOSITION PRESSURE AT 302°.

The next experiments were made in a bath of diphenylamine vapor. The first method used was an indirect one. It consisted in heating the silver oxide in a closed glass tube which was drawn out at one end to a capillary; cooling it suddenly by removal from the bath; opening the capillary under a gas burette; and calculating from the volume of gas thus collected and from the volume of the tube (exclusive of that occupied by the remaining mixture of silver and oxide) the pressure which had been exerted in the tube at the temperature of the bath. Eight tubes containing different quantities of silver oxide were suspended in the vapor of boiling diphenylamine contained in a large iron receptacle, and were kept in this bath for six days. During this time it was found necessary to renew the diphenylamine several times on account of its gradual decomposition. The pure substance (Kahlbaum's) boiled at 302°. In the course of the experiment several of the tubes were broken; in others the oxide had entirely decomposed, so that finally only one tube of the eight could be used for determining the pressure. This was broken under water and 8.58 cc. of oxygen was collected in the burette at 760 mm. and 30°. The tube was weighed, then filled with ether, boiled to drive out all the air, filled again and weighed. From these two weighings the volume of the tube was found to be 0.92 cc. The pressure at 302° must therefore have been $\frac{8.58+0.92}{0.92}\,\frac{273+302}{273+30}$, or 18.0

atmospheres. It will be shown presently that this value is too small. The oxide used in this tube was Sample A, which decomposes, as I have shown, far more slowly than B. It is probable that equilibrium had not been established when the experiment was ended. On account of this difficulty of determining when the reaction had come to equilibrium, the indirect method was abandoned and the following adopted:

Two tubes, one having a bore of about 0.7 mm., the other of 3mm., were joined together and then drawn apart at the junction to a fine capillary about 1½ m. long (BCD in Fig. 1). In the smaller tube D, a short column of mercury was introduced, and the open end sealed, thus making an ordinary closed manometer, which was calibrated in the usual way after the conclusion of the experiment. The tube B was filled with silver oxide and the open end sealed.

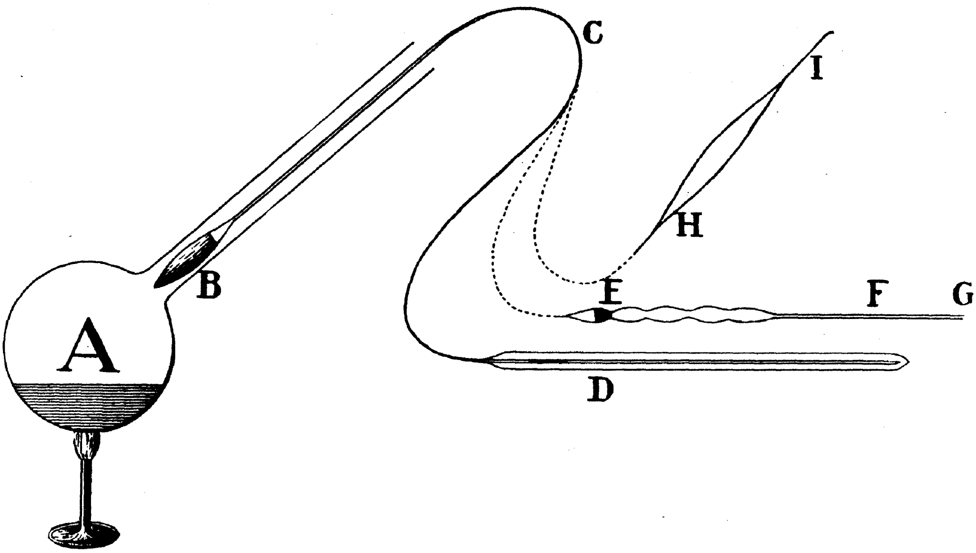

Fig. 1.

The large bath used in the preceding experiment had also to be abandoned on account of the great consumption of dyphenylamine, of which only a limited supply was available. A simple bath consisting in a long-necked glass flask was found to answer the purpose. The neck of the flask was about 2 cm. in diameter and was insulated externally by a coat of asbestos. The temperature in different parts of the neck was frequently tested and the variation over a considerable range rarely amounted to half a degree. The tube B was held in a simple framework of glass which prevented it from touching the sides of the flask.

In the preceding paper I have shown that the decomposition of silver oxide is extremely slow until a large amount of silver has formed, which acts as a catalyzing agent. Therefore, in order to hasten the attainment of equilibrium, the tube at the beginning of the experiment was heated to a higher temperature than that of the bath until a small part of the oxide was decomposed. The tube was then introduced into the bath and heated continuously, except that at the end of each day it was removed and the diphenylamine renewed. After being replaced in the bath the pressure always returned at once to its previous value, thus showing that during the rapid cooling and heating the reaction had not proceeded to any appreciable extent. During the experiment the temperature varied, chiefly on account of the gradual decomposition of the diphenylamine, between the 301.5° and 303°. We may take 302° as the average temperature. It may be noted here that 1° difference in temperature makes a difference in pressure of a little less than half an atmosphere.

The first experiment was made with sample B of the oxide. After being inclosed in the tube it was heated gently with a Bunsen flame until white spots began to appear in it. It was then introduced into the bath, the manometer indicating 6 atmospheres. At the end of two days the pressure had reached 16.7 atmospheres and was increasing very slowly. The tube was then removed from the bath and heated until a little more of the oxide was decomposed. When replaced in the bath the pressure was 20.2 atmospheres. During the next twenty-four hours the pressure remained constant at this point within one-tenth of an atmosphere. The tube was again removed and heated until, on being replaced, 23.2 atmospheres was registered. In the next twenty-four hours this pressure fell to 21.6 and in twenty-four hours more to 21.5 atmospheres.

This experiment shows that the decomposition pressure at 302° must be considerably above 16.7 atmospheres (contrary to the conclusions of LeChatelier, who placed it between 10 and 15 atmospheres), it is probably not far from 20.2 and it certainly is not greater than 21.5.

The experiment was then repeated with another tube containing the same kind of oxide. In this case a longer time was allowed for equilibrium to become established. Table III shows the pressure at the end of each twenty-four hours.

TABLE III.

Time in days.	Pressure in atmospheres.
1	11.1
2	15.1
3	17.3
4	18.8
5	19.5
6	19.7
7	19.7
8	19.7

It is evident from these two experiments that the correct pressure must lie between 19.7 and 21.5, and probably nearer to the former value than to the latter. Let us take 20.5 as a value sufficiently exact for our purposes.

THE DECOMPOSITION PRESSURE AT 445°.

The next experiments were made in sulphur vapor, the bath being arranged as in the last experiment. At this temperature also, the first attempts were made with an indirect method. The simple method previously used seemed hardly likely to succeed here, as a change of equilibrium in the tube would probably occur during the process of cooling from the temperature of boiling sulphur. A new method was therefore adopted. The construction of the apparatus is indicated in fig. 1 by B C H I. A thick-walled, glass tube of not more than 2 mm. internal diameter was drawn out to form a long capillary C. The tube B on one side of the capillary was filled with silver oxide and closed at the free end. The tube was again drawn to a capillary at I and sealed, leaving about 3 or 4 cm. between H and I. During this construction a small piece of tar was placed loosely in the tube where it narrowed to a capillary at H. When the apparatus had been in the bath long enough for equilibrium to be established a hot glass rod was brought for a moment in contact with the tube at H, thus melting the tar and causing it to run into the capillary. This heating was purely local and had no appreciable effect on the temperature of the gas in the tube H I. After the tar had solidified the capillary was broken at C leaving in the tube H I the original pressure. The capillary I could then be opened under water and the pressure calculated from the volume of gas evolved and the volume of the tube H I.

While this method was being used, experiments were also made with a direct method, a manometer being finally constructed which gave very satisfactory results. It is shown as E F G in fig. 1. B C E F G was drawn from a single tube of the kind used in the preceding method. At E it was drawn into a series of small bulbs, as these proved to be stronger than a single straight tube, and finally it terminated in a long capillary which had a nearly uniform bore (about 0. 1 mm.) in the region F G. The pressure was registered by a small mercury column standing at E at atmospheric pressure, and at a point F, about 10 cm. from the end of the capillary, when the pressure reached its maximum. On breaking the tube at C after the experiment, the mercury column invariably returned to its initial position at E. The capillary point at G was then broken off within one or two tenths of a millimeter from the end, and the volumes F G and E G were determined by drawing in mercury successively to F and to E and weighing the quantities drawn in. The smaller amount being only a few milligrams was weighed on a fine assay balance. I believe that this manometer gives pretty accurate results. The error caused by the capillarity of the mercury is not over one-tenth of an atmosphere, nor is it likely that the change in volume of the capillary tube when the pressure is exerted from within is large enough to cause any great error.

Two difficulties were met in the use of both the methods which I have described. At the high pressure of about 200 atmospheres which is here reached, the glass tubes are likely to explode upon the slightest provocation. Fortunately, although explosions in the external tube were frequent, the tube B within the bath rarely gave way. This difference between tubes of the same form and drawn from the same piece of glass is doubtless to be attributed to the annealing and toughening of the glass at the temperature of the bath. The danger of explosion in the outer tube was reduced as far as possible by choosing flawless tubes and drawing them with care. The capillaries never burst and probably could have withstood a much greater pressure than that to which they were subjected. On account of their flexibility and strength they form an excellent means of communicating high pressures.

The other difficulty was that ordinarily enough silver oxide could not be packed into the tube B to give the pressure of equilibrium before being entirely decomposed. This difficulty was overcome by filling only one-half of the tube with silver oxide, the rest being filled with powdered potassium permanganate. The latter decomposes at once at the temperature of the bath and produces a much larger quantity of oxygen than the same volume of silver oxide. The two substances were separated by a small piece of asbestos.

Experiments in which the manometer was used showed that equilibrium was reached in from fifteen to forty minutes, according to the kind of oxide used. In one case an addition was made to the apparatus in an extra bulb at C filled with potassium permanganate. After the manometer had come to rest as usual, the bulb at C was gently heated causing a further increase of pressure, but this excess of pressure rapidly disappeared through the reoxidation of the silver in B and within ten minutes the pressure was the same as before, within a small fraction of an atmosphere. This shows that we are dealing here with a case of true equilibrium.

The first experiments with both methods gave disappointing results. The pressures calculated with the aid of Boyle's law, ranged between 175 and 200 atmospheres. Those obtained by the indirect method were on the average several per cent higher than those obtained with the manometer. However, this difference disappears when allowance is made for the difference in compressibility[5] of air and oxygen contained respectively in the tubes EG and HI.

A more careful investigation of the temperature in the neck of the flask pointed to the cause of the observed variations in pressure. Although a preliminary test had shown the temperature to be the same in the neck and the body of the flask this proved not to be the case always. The temperature in the neck was found to vary considerably when the conditions, such as the angle at which the flask is held, and the height of the heating flame, were changed. This difference between the sulphur and diphenylamine baths is probably not so much due to the higher temperature of the former as to the great viscosity of the sulphur condensing in the neck of the flask.

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[5] Amagat, *Ann. de Chim.* (5) (1880), **19**, 345; (5) (1881) **22**, 353.

The tube containing the silver oxide had been placed in the neck rather than in the body of the flask in order to avoid possible variations of temperature due to spattering of the superheated liquid. Upon experiment, however, this superheating proved to be small. The Reichsanstalt standard thermometer showed the temperature of the liquid to vary under varying conditions between 445° and 445.5°, the temperature in the body of the flask between 443.5° and 444.5°. Since the thermometer may have been in error by 1 or 2 degrees (it was calibrated at 397° and 505°) we will use, as the temperature in the body of the flask, 445°, the accepted value for the boiling point of sulphur.

Four new experiments were now made similar to those already described except that the tube B containing the oxide was now placed entirely in the body of the flask. The direct method with the manometer was used.

For illustration I will give the details of the first of these experiments. The mercury column, moving rapidly at first, gradually came to rest. Its position was read on a scale attached to the capillary. Table IV gives the distances of this column from the end of the manometer at intervals of about five minutes. The experiment was begun at 10:25:

TABLE IV.

Time.	Distance in mm.
10.32	65.0
10.35	53.9
10.40	49.0
10.45	45.9
10.50	45.5
10.55	45.2
11.00	45.2
11.05	45.2
11.10	45.3
11.15	45.2
11.25	45.2

The apparatus was now broken at C and the manometer calibrated; 0.842 grams of mercury was required to fill the whole manometer, 0.00413 grams to fill the end of the capillary to the point (45.2 mm.) where the mercury came to rest. If we assume Boyle's law to be correct the pressure is $\frac{0.842}{0.00413}$, or 204 atmospheres.

The results of this experiment and those of others made under the same conditions are given in Table V.

TABLE V.

No. of experiment.	Kind of Oxide.	Pressure.
1	B	204
2	B	191
3	B	200
4	A	205

Experiment 2 differed from the others in that the silver oxide was almost entirely used up. The result is undoubtedly too low. Discarding this value therefore and taking the average of the other three the result is 203 atmospheres.

The preceding calculations have been based on the assumption that the air in the manometer obeys Boyle's law. According to the work of Amagat[6] the true pressure of air in the neighborhood of 200 atmospheres is, at 0°, about 2½ per cent higher than that calculated from the volume by Boyle's law. At 30°, the temperature of the manometer, this correction would be somewhat less, say two per cent. Making this correction, therefore, we get 207 atmospheres as the equilibrium pressure of silver oxide at 445°.

DOES SILVER SUBOXIDE EXIST?

M. Guntz[6] heated silver oxide to a temperature of 358° for fifty hours and obtained a pressure of 49 atmospheres. This he considered the pressure of equilibrium in the reaction

$$2\ Ag_4O = 8\ Ag + O_2$$

and cited as evidence for this view the following experiment.

In a closed tube were placed known weights of silver and silver oxide and a quantity of potassium permanganate sufficient to yield enough oxygen to produce a pressure higher than 49 atmospheres at 358°. The whole was heated at this temperature for three days. The tube was then cooled rapidly and it was found that the silver had gained in weight and the silver oxide had lost in weight by amounts which indicated the formation of Ag_4O in both cases.

I shall presently show that in all my experiments carried on at temperatures from 300° to 445°, and with two different samples of silver oxide, the suboxide of silver was never formed. It seems difficult to reconcile my results with those of M. Guntz. Of course, it is conceivable that the suboxide is capable of existence and that it appeared for some reason in one case and not in the other, just as occasionally some hydrate may be suddenly precipitated from an aqueous solution although it may fail to appear many times under apparently similar circumstances. However, I am inclined to believe that the experiments of M. Guntz can be explained without the necessity of assuming the existence of the suboxide. If the pressure in the tube that he used was greater than the

[6] L. c.

decomposition pressure of silver oxide, the gain in weight of the silver can be readily explained by its oxidation to silver oxide. The loss in weight of the silver oxide can only be explained by assuming that it contained water or carbon dioxide. I should consider this improbable if it were not for the fact that my own experiments have shown how difficult it is to prepare and to keep silver oxide free from these impurities. It is perhaps not generally known that carbon dioxide, as well as water, is rapidly taken up by silver oxide from the atmosphere. One sample which I prepared in such a way that it was absolutely free from this impurity absorbed a considerable quantity of carbon dioxide while standing for a month in a loosely corked bottle. When carbon dioxide and water are once present, they can be expelled only with great difficulty. Some of the former frequently remains after the silver oxide has been heated an hour or two at 300°.

That silver suboxide was not present in any of the experiments I have described will be evident from the following considerations. According to the phase-rule, silver, silver oxide, silver suboxide, and oxygen can not all exist together in equilibrium. In the absence of suboxide only one state of equilibrium is possible, that between Ag, Ag_2O, O_2. But in case the suboxide could form, then two states of equilibrium would be possible, namely between Ag_2O, Ag_4O, O_2, and between Ag_4O, Ag, O_2. With a given quantity of silver oxide enclosed in a small volume the first equilibrium would exist; in a larger volume, the second.

In all the experiments previously described the final mixture in the tube has contained silver, as shown by the color and by the metallic flakes produced upon grinding the whole in a mortar. In any given case, therefore, the remaining black powder must be a single phase, either all silver oxide or all silver suboxide. Let us assume that it is the latter and see to what consequences we are led. For example, let us assume that the pressure of 32 atmospheres which we obtained at 325° is the decomposition pressure of silver suboxide. Now suppose that we inclose so much silver oxide in a tube that if it should all decompose according to the reaction,

$$4\ Ag_2O = 2\ Ag_4O + O_2$$

a pressure of over 32 atmospheres would result. Then metallic silver could not form and the only possible equilibrium would be that between the oxide and suboxide.

This very experiment was undertaken. A glass tube was filled with silver oxide, sealed, and heated for a week at 325°. At the end of this time a considerable quantity of silver had formed, although, calculated from the volume of the tube and the amount of oxide, over 100 atmospheres would have been generated by the change from the oxide to the suboxide alone. A similar experiment was made at 345°. A small quantity of silver was placed in a tube and covered with a little glass wool.

The rest of the tube was filled as full as possible with silver oxide. The tube was then sealed and left in the thermostat for five days, at the end of which time not only was the silver unoxidized but white spots of silver had appeared throughout the oxide.

These experiments show pretty conclusively the absence of silver suboxide. A still stronger proof is given by the experiments at 302°. In one of the experiments at this temperature which showed the pressure of equilibrium to be about 20 atmospheres, the volume of the tube and the manometer and the weight of silver oxide were determined. It was found that enough oxide had been used to produce a pressure of 35 to 40 atmospheres if it had all changed to suboxide, yet a considerable quantity of silver was found in the final mixture.

Finally, it was found possible to show by direct analysis that the black powder left in the tubes was not silver suboxide. It sometimes happened that at the end of the experiment the silver oxide was almost entirely decomposed in one part of the tube and apparently unchanged in another. This was due to the fact that the decomposition being autocalytic in character, progresses very rapidly at any point where it has once begun. In the first experiment at 302° a considerable portion of the black substance left in the tube appeared to contain no silver. A sample of this weighing 0.0892 grams was heated in a tube connected with a gas burette. It yielded 4.71 cc. of oxygen (at 27°, 760 mm.). The above quantity of pure silver oxide should give theoretically 4.73 cc. This is an unexpectedly good agreement.

In the experiments at 445° there was no case in which the remaining oxide did not contain some silver, but two samples were chosen which appeared to be least decomposed; 0.205 grams of the first gave 7.24 cc. of oxygen (calculated for Ag_2O, 10.85 cc.; for Ag_4O, 5.42 cc.); 0.0851 grams of the second gave 4.35 cc. (calculated for Ag_2O, 4.52 cc.; for $Ag_4\,O$, 2.26 cc.). It is obvious that here also the black substance can not be silver suboxide and is presumably silver oxide mixed with a certain amount of silver.

THE HEAT OF FORMATION OF SILVER OXIDE.

We have now obtained the pressure of equilibrium at different temperatures between silver, oxygen, and a certain black powder. We have proved that this black powder is not silver suboxide, but that at 302°, and presumably at the other temperatures as well, it has exactly the composition, Ag_2O. There still remains the possibility that this substance, although of the same composition as the silver oxide which exists at ordinary temperatures, may be an allotropic phase. In other words, there may be a transition temperature between room temperature and the temperatures of our experiments at which a break in continuity of the properties of silver oxide occurs. This possibility must be eliminated before we can safely calculate the decomposition pressure of silver oxide at 25° from the pressures at the higher temperatures.

In order to decide whether we are dealing with the same phase of silver oxide at high and low temperatures, we will determine from a change of the decomposition pressure between 302° and 445° the heat of decomposition of the silver oxide occurring at these temperatures, and compare this value with the one obtained at ordinary temperatures by other methods.

The heat of decomposition may be found from the change of pressure with the temperature, by the aid of the equation of van't Hoff, which in this case has the form,

$$\frac{dlnp}{dT}=\frac{Q}{RT^2} \qquad (1)$$

where p is the decomposition pressure, T the absolute temperature, R the gas constant, and Q the heat absorbed when 2-gram molecules of silver oxide decompose according to the equation,

$$2\ Ag_2O = 4\ Ag + O_2.$$

This equation of van't Hoff is not strictly exact, but is derived with the aid of two assumptions from the equation of Clausius,

$$\frac{dp}{dT}=\frac{Q}{T\ (v-V)} \qquad (2)$$

where v is the molecular volume of oxygen at the temperature T and the pressure p, V is the total change of volume of the solid system—that is, it is the volume of 2-gram molecules of silver oxide less that of 4-gram molecules of silver. Q represents the heat absorbed during the decomposition and may be replaced by the expression $U + p\ (v - V)$, where U is the increase in internal energy accompanying the decomposition, and $p\ (v - V)$ is the work done. In the integration of the van't Hoff equation U is usually regarded as constant, but since we are dealing with a pretty wide range of temperature we shall obtain a more accurate result by regarding it as a linear function of the temperature according to the equation

$$U=U_0-C\ T \qquad (3)$$

Where C is the diminution in the heat capacity of the system during the decomposition of two gram-molecules of silver oxide. We may therefore write in place of the equation 2,

$$\frac{dp}{dT}=\frac{U_0-CT+p\ (v-V)}{T\ (v-V).} \qquad (4)$$

In order to obtain equation 1 from equation 2 or 4, it is necessary to make two assumptions; first that the oxygen obeys the gas law, and second, that the volume V is negligible compared with v. Since the deviation of oxygen from the gas law is small at ordinary temperatures[7] and is undoubtedly much smaller at the temperature of our experiments, the first assumption will not lead to any appreciable error. The second assumption would also be justifiable if it were not for the fact that in our experiments at 445° the pressure is so great, and consequently the volume v so small, that in comparison with it V is large enough to be considered.

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[7] **Amagat (l. c.).**

Regarding V not as a negligible but as a constant quantity and assuming that $pv = RT$, I have succeeded in obtaining the following integrated form of equation 4,

$$ln \frac{p}{p_2} = -\frac{U_0}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right) + \frac{V}{R}\left(\frac{p_1}{T_1} - \frac{p_2}{T_2}\right) + \frac{R-C}{R} ln \frac{T_1}{T_2}.$$ [8]

With the aid of this equation we are able to calculate from the decomposition pressures at any two temperatures the value of U_0. In order to do this we must know the values of V and C. The terms in which these quantities occur are comparatively unimportant ones in the equation and since both these quantities can be disregarded altogether without very seriously influencing the result, their approximate values will suffice.

From the tables of Landolt and Börnstein we find for the densities of silver and silver oxide 10.5 and 7.5, respectively. Calculating from these the molecular volumes we get approximately 20 cc. as the value of V.

The specific heat of silver oxide has not been determined, but the value of C may be found from the principle of the constancy of the atomic heat in solids. The heat capacity of silver is doubtless approximately the same in the oxide and in the metal. C, therefore, is the difference between the heat capacity of oxygen in the gaseous and solid states. The heat capacity at constant volume of 32 grams of oxygen in the gaseous state is 5 calories per degree. The heat capacity in the solid state is about 8.[9]. Whence C equals 3.

We will determine the value of U_0 in calories and therefore use for R the value 2.0, except in the next to the last term of equation 5, in which, if the pressure is expressed in atmospheres and the volume in cubic centimeters, R must be expressed in corresponding units and given the value 83.

We have three sets of experimental values (*a*) $T = 445 + 273$, $p = 207$; (*b*) $T = 302 + 273, p = 20.5$; (*c*) $T = 325 + 273$, $p = 32$. These may be used in equation 5 in pairs. Using values (*a*) and (*b*) the first term of the equation, $1n \frac{p_1}{p_2}$ has the value 2.31; the third term,

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[8] This equation may readily be verified by differentiating it. The resulting equation by suitable transposition and with the aid of the equation $pv.=RT$, can readily be shown to be identical with equation 4. Equation 5 may also be obtained by an independent method from equations 6 and 7 of my paper entitled "Law of Physico-Chemical Change." (*Zeit. Phys. Chem.* (1901) **38**, 205.)

[9] See, for example, Ostwald's Lehrbuch.

0.06; the fourth term, — 0.11. Combining these, we get for the second term the value 2.36, whence U_0 is 13,600 in small calories.

Using similarly values (*a*) and (*c*) we find for U_0 the same value, 13,600 calories.

From values (*b*) and (*c*) we find $U_0 = 13,300$. This value is to be given less credit on account of the nearness of the two temperatures used.

The remarkably good agreement between these values shows conclusively that we are dealing with the same reaction throughout the whole range of temperature from 302° to 445°. As final result we will take, $U_0 = 13,600$ small calories, or 136 K (Ostwald calories). From equation 3 the value of U at room temperatures is therefore between 127 K and 128 K. This is the increase of internal energy accompanying the decomposition of 2-gram molecules of silver oxide. The heat of formation of silver oxide at room temperatures, exclusive of external work, is therefore one-half this value or 64 K.

HEAT OF FORMATION OF SILVER OXIDE, OTHERWISE DETERMINED.

For the heat of formation of silver oxide we find in the literature only two determinations which are at all trustworthy. Thomsen[10] allowed copper to act upon silver nitrate and from the heat of this reaction, the heat of formation of copper nitrate, and the heat of neutralization of silver oxide, calculated the heat of formation of the latter to be 59 K (*a*). Berthelot[11] by a similar method obtained 70 K (*b*).[12]

In his experiments on the energetics of galvanic elements, Jahn[13] obtained the following equation:

$$Pb + 2\,AgNO_3,Aq = Pb\,(NO_3)_2,Aq + 2\,Ag + 509\text{ K}.$$

Let us combine this equation with the following:

$$PbO + 2\,HNO_3,Aq = Pb\,(NO_3)_2,Aq + H_2O + 178\text{ K (Thomsen)}$$
$$Pb + O = PbO + 503\text{ K (Thomsen)}$$
$$Ag_2O + 2\,HNO_3,Aq = H_2O + 2\,AgNO_3,Aq + 104\text{ K}^{14}\text{ (Berthelot)}$$

Whence

$$2\,Ag + O = Ag_2O + 68\text{ K }(c)$$

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[10] Not having Thomsen's book at hand, the values here attributed to him are taken from Ostwald's Lehrbuch.

[11] *Ann. de Chim.* (1878) **15**, 186.

[12] All these values are for the "total" heats of reaction. I have chosen to use these values, which include the external work, since they are the ones commonly given in the literature. The reduction to the simple "internal" heat of reaction will be made later.

[13] *Wied. Ann.* (1886) **28**, 493.

[14] This value will be discussed presently.

Recently Jouniaux[15] has determined the conditions of equilibrium at several temperatures between silver, hydrochloric acid gas, silver chloride and hydrogen, and has thus obtained the thermo-chemical equation,

$$\mathrm{HCl\ (gas)} + \mathrm{Ag} = \mathrm{AgCl} + \mathrm{H} + 71\ \mathrm{K}^{16}$$

Let us combine with this equation the following equations of Berthelot:

$$\mathrm{HCl\ (gas)} + \mathrm{Aq} = \overset{+}{\mathrm{H}} + \overset{-}{\mathrm{Cl}} + 174\ \mathrm{K}.$$
$$\overset{+}{\mathrm{Ag}} + \overset{-}{\mathrm{Cl}} = \mathrm{AgCl} + \mathrm{Aq} + 157\ \mathrm{K}.$$
$$\tfrac{1}{2}\ \mathrm{Ag_2O} + \overset{+}{\mathrm{H}} = \overset{+}{\mathrm{Ag}} + \tfrac{1}{2}\ \mathrm{H_2O} + 52\ \mathrm{K}.$$
$$\mathrm{H} + \tfrac{1}{2}\ \mathrm{O} = \tfrac{1}{2}\ \mathrm{H_2O} + 345\ \mathrm{K}.$$

Whence

$$2\ \mathrm{Ag} + \mathrm{O} = 2\ \mathrm{Ag_2\ O} + 66\ \mathrm{K}\ (d).$$

I have measured the E. M. F. of the following cell,[17]

$$\mathrm{Hg} \;\Big|\; \mathrm{HgCl} \;\Big|\; \mathrm{KCl}\frac{\mathrm{N}}{10} \;\Big|\; \mathrm{KNO_3}\frac{\mathrm{N}}{10} \;\Big|\; \mathrm{AgNO_3}\frac{\mathrm{N}}{10} \;\Big|\; \mathrm{Ag}$$

and found it to be 0.429 — 0.00120t, volts, where t is the temperature Centigrade. From these figures the Helmholtz equation gives $\mathrm{Hg} + \overset{-}{\mathrm{Cl}} + \mathrm{Ag} = \mathrm{Ag} + \mathrm{HgCl} + \mathrm{Aq} + 175\ \mathrm{K}$. With this equation we will combine the following:

$$\tfrac{1}{2}\ \mathrm{Ag_2O} + \overset{+}{\mathrm{H}} = \overset{+}{\mathrm{Ag}} + \tfrac{1}{2}\mathrm{H_2O} + 52\ \mathrm{K}^{18}$$
$$\mathrm{HgCl} + \mathrm{Cl} = \mathrm{HgCl_2} + 219\ \mathrm{K}^{19}$$
$$\mathrm{Hg} + 2\ \mathrm{Cl} = \mathrm{HgCl_2} + 533\ \mathrm{K}^{20}$$
$$\mathrm{Cl} + \tfrac{1}{2}\ \mathrm{H_2O} + \mathrm{Aq} = \overset{-}{\mathrm{Cl}} + \overset{+}{\mathrm{H}} + \tfrac{1}{2}\mathrm{O} + 50\ \mathrm{K}.^{21}$$

Hence

$$2\ \mathrm{Ag} + \mathrm{O} = \mathrm{Ag_2O} + 74\ \mathrm{K}\ (e).$$

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[15] *C. R.* (1903) **132**, 1270.

[16] I have added 3K to the value given by Jouniaux in order to obtain the "total" heat of reaction.

[17] The details will be given in the following paper.

[18] Thomsen gives 54 K, but Berthelot found 52 K by the neutralization of silver oxide by nitric acid (*Ann. de Chim.* (5) (1875) **4**, 188), and also precipitation with alkalies (*ibid* (5) (1375) **4**, 503) and has recently verified the value by new experiments (*C. R.* (1901) **133**, 555).

[19] This value was obtained by Thomsen from the direct action of chlorine upon calomel. It is in all probability correct, as it has not been called into question in the critical work on mercury salts of Nernst (*Zeit. Phys. Chem.* (1888) **2**, 22) and Varet (*C. R.* (1893) **120**, 620 and 921).

[20] This value was obtained independently by both Nernst and Varet (l. c.).

[21] Thomsen's value is 50.5 K (*Pogg. Ann.* (1873) **148**, 177). Berthelot's is 48 K (*C. R.* (1889) **109**, 546 and 590). Thomsen's value is probably the more accurate.

We have thus found five independent values of the heat of formation of silver oxide, varying from 59 K to 74 K. These values all include the external work. In order to obtain the mere change of internal energy, 3 K must be subtracted from each of the above numbers. We have then,

(*a*)	56
(*b*)	67
(*c*)	65
(*d*)	63
(*e*)	71

The average of these values is 64 K, which happens to be precisely the value which we obtained in the preceding section. This very satisfactory agreement proves conclusively that the silver oxide which exists between 302° and 445° is, from a thermo-dynamic point of view, identical with that which exists at ordinary temperature.

DECOMPOSITION PRESSURE OF SILVER OXIDE AT 25°.

We are now able to calculate from equation 5 the equilibrium pressure between silver oxide, silver, and oxygen at 25°. As data we will take 20.5 atmospheres as the pressure at 302°; 64 K as the heat of formation of silver oxide at 25°; and for C the value 3, as before. The third term of the equation containing V may be here neglected. We thus obtain $p_{25} = 4.9 \cdot 10^{-4}$ atmospheres.

When we consider the question of how much this value is affected by possible errors in the data used, we find that errors in p_{302} and in C have much less influence than an error in U_{25}. An error of 1 K in the latter would cause an error of nearly 20 per cent in p_{25}. In the following paper I shall show that from this value of the decomposition pressure of silver oxide at 25° it is possible to calculate the electrolytic potential of oxygen and that the value thus obtained differs very considerably from the one at present accepted.

SUMMARY.

The equilibrium pressures in the system, silver oxide, silver and oxygen, at the temperatures 302°, 325°, and 445° are shown to be respectively 20.5, 32 and 207 atmospheres.

It is proved that no silver suboxide was present in any of the experiments and that probably it is incapable of existence at these temperatures.

From the change of equilibrium pressure with the temperature, the heat of formation of silver oxide is found to be 64 K (Ostwald calories).

The mean of five determinations of this quantity based on calorimetric data is likewise 64 K.

The decomposition pressure of silver oxide at 25° is calculated to be about $4.0 \cdot 10^{-4}$ atmospheres.

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